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Honourable Richard Hurlburt
Minister

P. C. Underwood
Deputy Minister

Halifax, Nova Scotia
2004

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Cover photo

Brecciated metasiltstone with pyrite, chalcopyrite and specularite from the Mt. Thom iron oxide-copper-gold prospect, northern Nova Scotia. Photo courtesy of Avalon Ventures Ltd.

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Table of Contents

Page

Mineral Resources Branch Activities

Digital Information Services - *B. E. Fisher, J. C. Poole and J. S. Saunders* 1

Multi-element Distribution in Humus, Soil, Till, Rock and Tailings Associated with Historic Gold Districts of the Meguma Zone, Nova Scotia, Canada - *T. A. Goodwin, P. K. Smith and M. B. Parsons* 7

Reclamation of the Irish Cove Limestone Quarry (NTS 11F/15), Richmond County - *D. B. Hopper and F. J. Bonner* 15

Geological Report on the Early Stages of Development of the Mooseland Gold District (NTS 11D/15), Halifax County - *R. J. Horne, G. Covey and C. Albert* 25

Geology of the Southern Lobe of the Brazil Lake LCT-type Pegmatite (NTS 21A/04), Yarmouth County, Nova Scotia - *D. J. Kontak* 41

Geoscience Editing and Publishing - *D. R. MacDonald, B. L. MacDonald and J. S. Saunders* 69

Mineral Exploration Activity in Nova Scotia, 2003 - *P. D. McCulloch* 73

Assistance to Prospectors and Small Developers at the Nova Scotia Department of Natural Resources - *R. F. Mills* 85

Progress Report on a New Mapping and Resource Evaluation Program for Central Nova Scotia - *R. D. Naylor, B. E. Fisher, P. S. Giles, T. A. Goodwin, D. J. Kontak and P. J. Harvey* 87

Mineral Inventory Project Activities for 2003 - *G. A. O'Reilly and G. J. DeMont* 93

Age and Petrochemistry of Mafic Sills in Rocks of the Northwestern Margin of the Meguma Terrane, Bear River - Yarmouth Area of Southwestern Nova Scotia - *C. E. White and S. M. Barr* 97

External Abstracts and Conference Presentations

Petrological Studies of Mafic Pegmatites in the Jurassic North Mountain Basalt, Nova Scotia: A Record of Extreme Fractionation in the Late-stage Evolution of Continental Tholeiites - *C. Baldwin, D. J. Kontak and J. Dostal* 119

Significance of U-Pb Detrital Zircon Ages in Quartzite from peri-Gondwanan Terranes, New Brunswick and Nova Scotia, Canada- - *S. M. Barr, D. W. Davis, S. Kamo and C. E. White* 120

U-Pb Ages of Detrital Zircon in Quartzite from Avalon and Adjacent Terranes, New Brunswick and Nova Scotia, Canada - *S. M. Barr, D. W. Davis, S. Kamo and C. E. White* 121

Page

U/Pb, Re/Os and Ar/Ar dating of the South Mountain Batholith and its Mineral Deposits - *S. Carruzzo, D. J. Kontak, P. H. Reynolds, D. B. Clarke, G. R. Dunning, D. Selby and R. A. Creaser*.....122

Communicating the Relevance of Earth Science with a Geological Highway Map - *H. V. Donohoe, Jr., B. E. Fisher, R. Raeside, K. Silverstein, D. Skilliter and C. E. White*.....123

Chemical and Isotopic (Pb, Sr) Zonation in a Peraluminous Granite Pluton: Origin by Crystal-fluid Fractionation - *J. Dostal, A. K. Chatterjee and D. J. Kontak*.....124

$^{40}Ar/^{39}Ar$ Age of the Jurassic North Mountain Basalt, Southwestern Nova Scotia - *D. J. Kontak and D. A. Archibald*.....125

Re/Os Analysis of Arsenopyrite from Meguma Lode Gold Deposits: Implications for Timing of Gold Metallogeny and Age of Acadian Deformation in the Meguma Terrane, Nova Scotia - *D. J. Kontak R. J. Horne, R. Morelli and R. Creaser*.....126

The Brazil Lake Pegmatite, Southwestern Nova Scotia: Role of Sodium Metasomatism in an LCT-type Pegmatite of Magmatic Parentage - *D. J. Kontak and T. K. Kyser*.....127

Gold in the Meguma Terrane, Southern Nova Scotia: Is There a Continuum between Mesothermal Lode Gold and Intrusion-related Gold Systems? - *D. J. Kontak, G. A. O'Reilly, M. A. MacDonald R. J. Horne and P. K. Smith*.....128

Petrology and Tectonic Setting of the Carboniferous Wedgeport Pluton, Southwestern Nova Scotia - *N. J. MacLean, S. M. Barr and C. E. White*.....129

Re-Os Arsenopyrite Geochronology of Quartz Veining and Au Mineralization, Meguma Terrane, Nova Scotia, Canada - *R.* Morelli, *R. Creaser, D. Selby, D. J. Kontak and R. J. Horne*.....130

Acadian Metamorphism with an Alleghanian Overprint: White Rock Formation, Yarmouth Area, Southwestern, Nova Scotia - *D. P. Moynihan, R. A. Jamieson, N. G. Culshaw and C. E. White*.....131

The Appalachian Glacier Complex - *R. R. Stea*.....132

Ice Stream Tills, Ice Divide Tills, and Reworked Tills in Nova Scotia, Canada - *R. R. Stea and P. W. Finck*.....133

Younger Dryas Glacierization in the Gulf of St. Lawrence, Canada - *R. R. Stea,, R. J. Mott D. I. Godfrey-Smith and J. L. Fastook*.....134

Late-glacial Ice Advances in Maritime Canada - *R. R. Stea, R. J. Mott, J. Gosse and J. Fastook*.....135

Stratigraphy, Structure, and $^{40}Ar/^{39}Ar$ Geochronology in the Lochaber-Mulgrave area, Nova Scotia - *P. J. Ténière, S. M. Barr, C. E. White, and P. H. Reynolds*.....136

Basement Blocks in Southwestern Cape Breton Island and Adjacent Mainland Nova Scotia, Canada, and their Relationship to the Avalon Terrane - *C. E. White, S. M. Barr, J. W. F. Ketchum and P. H. Reynolds*.....137

Page

A New Perspective on Stratigraphy, Deformation, and Metamorphism in the Southwestern Meguma Terrane, Nova Scotia - *C. E. White and R. J. Horne* 138

Appendix 1 - Mineral Industry Activity in Nova Scotia, 2002 139

Appendix 2 - Mineral Resources Branch Geoscience Maps and Publications for Sale 153

Digital Information Services

B. E. Fisher, J. C. Poole and J. S. Saunders

The Digital Information Services group is responsible for developing and maintaining the Mineral Resources Branch (MRB) Geographic Information System and associated databases, the NovaScan bibliographic geoscience database, for supplying digital data and services to clients and staff, and for developing and maintaining the MRB Internet web site. Permanent Digital Information Services staff consist of geologists / GIS specialists Brian Fisher and Jeff Poole, and web technicians Susan Saunders and Barbara MacDonald. Jeff McKinnon, a geologist / GIS specialist, was hired as a GIS assistant to work on projects for the federal-provincial Targeted Geoscience Initiative (TGI). Julie Beaumont, a GIS specialist, was hired in April and worked until December on TGI projects. Paul Barker, Collene Tuttle and Alia Bigio, geology students, were hired to work as GIS assistants during the summer of 2003.

Digital Geoscience Data Products

A collection of digital geology maps, databases and images of Nova Scotia (in DXF, ARC export, ArcView® shapefiles, TIFF, and JPEG formats in a UTM projection using the NAD27 datum, and in PDF format) has been developed, and is available for viewing or free download from the MRB web site (http://www.gov.ns.ca/natr/meb/pubs/pub3.htm). The complete list of digital data products available can be seen in Appendix 3. A licence agreement is issued with all digital data sets. This agreement allows unrestricted use of the data with the understanding that DNR remains the owner of the data and is not transferring copyright to the user. Since March 1999, when data were first made available for download from the MRB web site, there have been nearly 67,000 downloads.

Public Access GIS

A Public Access GIS has been developed for the use of clients in the DNR Halifax Library. This is a user-friendly query and display system that uses a customized version of ArcView® to access a variety of geographically referenced, digital geoscience data on Nova Scotia. It can display and query data sets, overlay various themes of geoscience, topographic and land-use information, and plot the resulting maps in colour.

GIS Development

Digital Information Services staff have been working cooperatively with MRB staff on several projects, including the Western Nova Scotia Aggregate Project. Paul Barker was hired for the summer to digitize and create databases for a number of bedrock and surficial maps required for that compilation.

The GIS version of the Registry of Mineral and Petroleum Titles database was updated several times. Five new versions (7, 8, 9, 10 and 11) of the Mineral Rights Disposition Map for the Province of Nova Scotia (Open File Map ME 2000-6) were released. The initial release of the Mineral Rights Database as a digital product took place in October 2003, with version 2 being released in November 2003.

Work has continued on converting 48 recently published bedrock geology maps and approximately 30 of the Faribault geological series maps from Fieldlog® / AutoCAD® format into ArcInfo® and incorporated as part of the branch GIS. These maps will be completed and released as digital products in 2004.

Internet Map Projects

Jeff Poole has created several prototype Internet Map Server (IMS) applications, currently running in-house, that will allow our clients to view, query, plot and download digital maps and databases over the Internet. Two applications have been created and are planned for release in early 2004. The first

Fisher, B. E., Poole, J. C. and Saunders, J. S. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 1-6.

is a compilation of geological maps and databases, including the Mineral Rights database, and the second is the Mineral Resource Land Use Atlas.

Targeted Geoscience Initiative Project in South-central Cape Breton Island

In the summer of 2000 the Geological Survey of Canada (Atlantic) and the Mineral Resources Branch were awarded funding under the Natural Resources Canada Targeted Geoscience Initiative (TGI) for a geological mapping project to aid mineral development in south-central Cape Breton Island. As part of this project, we are responsible for producing a digital compilation of geological data for this area. Jeff McKinnon and Julie Beaumont were assigned in April to work exclusively on this project to build databases, digitize maps and develop the digital products that will be produced as a result of this project. We have identified approximately 90 layers that may potentially be included as part of the final products. To date, approximately 20 maps have been digitized, several maps have been scanned, 6 geophysical images created, 38 geophysical maps created, and a number of other layers and databases have been developed for inclusion in the compilation. A web site for the project will be released early in 2004.

Targeted Geoscience Initiative Project in Central Nova Scotia

In the fall of 2003 the Geological Survey of Canada (Atlantic) and the Mineral Resources Branch were awarded funding under the Natural Resources Canada Targeted Geoscience Initiative (TGI) for a Carboniferous hydrocarbon and mineral potential project in central Nova Scotia. As part of this project we are responsible for producing a digital compilation of geological data for this area.

Canadian Geoscience Knowledge Network

The Canadian Geoscience Knowledge Network (CGKN) is a collaborative effort between the 12 provincial and territorial geoscience agencies and the Geological Survey of Canada, which operates six offices across Canada. The plan is for the CGKN to be a single window to access geoscience holdings of all the surveys using the Internet. In 2003 the branch continued to develop metadata describing digital data products and publications, and worked to bring the metadata server on-line. It is expected that metadata will be searchable over the Internet by CeoNET and the CGKN metadata search engine in March 2004.

Digital Products and Open File Maps Released in 2003

The following new digital products, open file maps, and updated versions of digital products were released in 2003. These can all be downloaded for free from the URL listed with the product.

Digital Products

DP 001b. Mineral Occurrence Database, version 6, December 2002. This database can be used with DP 001a, the Mineral Occurrence Query Program. (http://www.gov.ns.ca/natr/meb/download/dp001b.htm)

DP 002. Mineral Occurrence Database, version 6, December 2002. E00, DXF/DBF and SHP formats, http://www.gov.ns.ca/natr/meb/download/dp002.htm

O00-06. Mineral Rights Disposition Map for the Province of Nova Scotia, version 7 (June 27, 2002), version 8 (June 18, 2003), version 9 (August 20, 2003), version 10 (October 6, 2003) and version 11 (November 7, 2003), compiled by B. E. Fisher and A. S. Wenning, scale 1:500 000. Open File Map ME 2000-6. (http://www.gov.ns.ca/natr/meb/download/00o06.htm)

DP ME 51, Version 1, 2003, Nova Scotia Mineral Rights Database. Available in E00, SHP and DXF/DBF formats. Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp051.htm

DP ME 53, Version 1, 2003, Digital Version of Nova Scotia Department of Natural Resources Map ME 2000-8, Geothermal Resource Areas in the Province of Nova Scotia, scale 1:500 000, 2000. Available in E00, SHP, DXF/DBF and PDF formats. Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp053.htm

DP ME 59, Version 1, 2003, Digital Version of Nova Scotia Department of Natural Resources Open File Map ME 2003-1, Surficial Geology Map of the Whycocomagh Area (N.T.S. 11F/14), Inverness County, Nova Scotia, by R. R. Stea and M. Feetham, 2003, scale 1:50 000, Open File Map ME 2003-1. Available in E00, SHP, DXF/DBF and PDF formats (DP ME 59 was previously released in June 2003 in PDF format only). Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp059.htm

DP ME 62, Version 1, 2003, Airborne Magnetic Total Field, Calculated First Vertical Derivative and Calculated Second Vertical Derivative Images for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003. Available in TIFF and JPEG formats and also as PDFs of OFM ME 2003-2 to 16 and OFM ME 2003-33 to 35 (see next page). Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp062.htm

DP ME 63, Version 1, 2003, Bouguer Gravity and Residual Bouguer Gravity Images for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003. Available in TIFF and JPEG formats and also as PDFs of OFM ME 2003-17 to 26 and ORM ME 2003-36 and 37 (see next page). Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp063.htm

DP ME 64, Version 1, 2003, Airborne VLF-EM Total Field and Quadrature Images for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003. Available in TIFF and JPEG formats and also as PDFs of OFM ME 2003-27 to 32 and OFM ME 2003-38 and 39 (see next page). Download free from the MRB website at http://www.gov.ns.ca/natr/meb/download/dp064.htm

Open File Maps

OFM ME 2000-6. Mineral Rights Disposition Map for the Province of Nova Scotia, version 7, (June 27, 2003), version 8 (June 18, 2003), version 9 (August 20, 2003), version 10 (October 6, 2003) and version 11 (November 7, 2003), compiled by B. E. Fisher and A. S. Wenning, scale 1:500 000.

OFM ME 2003-1 Surficial Geology Map of the Whycocomagh Area (NTS 11F/14), Inverness County, Nova Scotia, by R. R. Stea and M. Feetham, 2003, scale 1:50 000

OFM ME 2003-2 Airborne Magnetic Total Field Map for Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-3 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-4 Airborne Magnetic Total Field Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-5 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-6 Airborne Magnetic Total Field Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-7 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-8 Airborne Magnetic Calculated Second Vertical Derivative Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-9 Airborne Magnetic Total Field Map for Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-10 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-11 Airborne Magnetic Total Field Map for NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-12 Airborne Magnetic Calculated First Vertical Derivative Map for NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-13 Airborne Magnetic Calculated Second Vertical Derivative Map for NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-14 Airborne Magnetic Total Field Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-15 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-16 Airborne Magnetic Calculated Second Vertical Derivative Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-17 Bouguer Gravity Map for the Western Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-18 Residual Bouguer Gravity Map for the Western Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-19 Bouguer Gravity Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-20 Residual Bouguer Gravity Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-21 Bouguer Gravity Map for NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-22 Residual Bouguer Gravity Map for NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-23 Bouguer Gravity Map for the Western Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-24 Residual Bouguer Gravity Map for the Western Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-25 Bouguer Gravity Map for the Western Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-26 Residual Bouguer Gravity Map for the Western Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-27 Airborne VLF-EM Total Field Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-28 Airborne VLF-EM Quadrature Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-29 Airborne VLF-EM Total Field Map for Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-30 Airborne VLF-EM Quadrature Map for Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-31 Airborne VLF-EM Total Field Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-32 Airborne VLF-EM Quadrature Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-33 Airborne Magnetic Total Field Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-34 Airborne Magnetic Calculated First Vertical Derivative Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-35 Airborne Magnetic Calculated Second Vertical Derivative Map for

Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp062.htm

OFM ME 2003-36 Bouguer Gravity Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-37 Residual Bouguer Gravity Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp063.htm

OFM ME 2003-38 Airborne VLF-EM Total Field Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

OFM ME 2003-39 Airborne VLF-EM Quadrature Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000. **Price $5.00.** Also available as a free PDF download from http://www.gov.ns.ca/natr/meb/download/dp064.htm

NovaScan

NovaScan is the bibliographic geoscience database on Nova Scotia and its offshore regions. As of December 31, 2003, the database contained 14,402 MRB records, consisting of 6,896 mineral exploration assessment and property reports, 3,702 publications, 2,774 open files, 808 theses, 195 contribution series, 12 digital publications, and 15 outside publications.

NovaScan was revised with 246 new records in 2003. The new records included 110 assessment and property reports, 63 publications, 48 open files, 6 contribution series and 19 theses.

In 2003, 112 assessment and property reports were publicly released from confidential status. Each month, a list of open assessment and property reports was generated from NovaScan and distributed to the DNR Library, the Core Library in Stellarton, and to the three Regional Geologists in Coxheath, Bible Hill and Bridgewater. Quarterly lists of open assessment and property reports were produced and published in the Nova Scotia Minerals Update newsletter.

In order to provide better service to our staff and clients by allowing Internet access (including search features) to NovaScan database, two independent projects were continued in 2003. The first project involved downloading the database into the MRB GIS and creating geographic boundaries for all NovaScan records. When complete, the NovaScan database will be searchable through MRB's Public Access GIS, and also searchable on the Internet. Completion of this project should take place in 2004.

The second project involved downloading and converting the NovaScan records into standard library MARC format, so that they could be loaded into the Provincial Library's Internet-accessible NcompasS catalogue database. This catalogue can be accessed at the following address: http://ncompass.library.ns.ca. After selecting your language of choice (English/French), select Nova Scotia Department of Natural Resources from the available catalogue listings, and you will then be able to search all the DNR Library records, including the NovaScan records. As of December 31, 2002, all non-confidential NovaScan records were entered into the NcompasS database. Newly released assessment reports, property reports, open files and publications are added to the NcompasS catalogue on a monthly basis.

Multi-element Distribution in Humus, Soil, Till, Rock and Tailings Associated with Historic Gold Districts of the Meguma Zone, Nova Scotia, Canada

T. A. Goodwin, P. K. Smith and M. B. Parsons[1]

Introduction

A three-year multi-disciplinary project was initiated in the spring of 2003 as part of the Geological Survey of Canada's Metals in the Environment (MITE) Program. The main objective of the project is to examine the distribution of metals in the environment associated with past producing gold districts throughout the province by characterizing regional and local background concentrations and speciation of the elements. Further, it is anticipated that off-site transport of the elements from mine waste such as tailings, and the transformation and fate of these elements in receiving environments can be quantified.

From 1862 to 1982, 1,198,619 troy ounces of gold were produced from over 50 gold districts in Nova Scotia (Bates, 1987). After crushing in a stamp mill, the gold was recovered from the host rock using one of three extraction methods: (1) gravity separation, (2) cyanidation and (3) mercury amalgamation. Historical records suggest that up to 25% of the mercury added during the amalgamation process was routinely lost to the tailings and to the atmosphere (Eaton, 1978). Arsenic, in the form of arsenopyrite, and other potentially harmful elements (Tl, Pb, etc.) are known to occur naturally in the host Meguma Group rocks, particularly in areas of gold mineralization (Lewis *et al.*, 1998).

In May 2003, all the provincial gold districts were evaluated using a criteria-based ranking system and ten districts were ultimately chosen for the initial stage of reconnaissance level multi-media sampling and subsequent evaluation. These sites were chosen using the following criteria: (1) known history of Hg amalgamation; (2) extensive tailings deposits; (3) no land ownership or mineral rights restrictions; and (4) little or no previous environmental work completed. The ten districts are located throughout southern Nova Scotia (Fig. 1), and encompass a wide range of environmental settings. The Nova Scotia Department of Natural Resources (NSDNR) sampling program involved the collection of humus, soil, till, rock and tailings. Analytical results are pending.

Additional research (not reported here) is also being carried out collaboratively by other government departments and universities (Parsons *et al.*, 2003). This research includes the collection and analysis of additional sample media including living plant material, surface waters and lake sediments, plus the acquisition of hyperspectral and radar data. At two sites (Lake Catcha and Lower Seal Harbour) processes controlling the formation of methyl mercury are also being investigated.

Geology and Geochemistry

Surficial Geology

Most of the surficial glacial deposits and associated landforms throughout Nova Scotia were formed during the Wisconsinan glaciation in the last 70 000 years (Lewis *et al.*, 1998). Superimposed till sheets and various multiple-flow directional indicators indicate that Nova Scotia is characterized by a relatively complex ice flow

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history (Stea *et al.*, 1992; Stea and Finck, 2001).

The oldest ice flow patterns mapped are toward the east and southeast and are responsible for the formation of the Hartlen Till associated with the Caledonia Phase (75-40 ka). This was followed by south and southwest ice flow of the Escuminac Phase (22-18 ka) and deposition of the Lawrencetown Till. During the Scotian Phase (18-15 ka), an ice divide was situated over Nova Scotia and the resulting ice flow varied from northwestward in northern Nova Scotia to south and southeast in southern Nova Scotia, followed by formation of the Beaver River Till. The Chignecto Phase (13-12.5 ka) was characterized by shifting ice flow associated with small ice caps, remnants of the waning stages of the Scotian Phase glacier (Stea and Finck, 2001).

Enrichment of gold and arsenic with lesser enrichment of copper, lead, zinc, tungsten, bismuth, tellurium and iron (plus other elements and minerals) characterize the gold deposits of the Meguma Terrane (Kontak and Smith, 1993). These elements (and minerals) are commonly geochemically enriched in soil and till down-ice from known gold mineralization (Coker *et al.*, 1988) resulting from mechanical dispersion (erosion, transportation and deposition) by advancing glacial ice. Dispersal distances vary in Nova Scotia from hundreds of metres to several kilometres down-ice from source (Stea and Finck, 2001).

Bedrock Geology

Lode gold deposits occur within the Meguma Zone underlying southern Nova Scotia. The associated auriferous quartz veins and minor disseminations are hosted by a 10 km thick succession of lower Paleozoic, turbiditic, meta-sediments consisting primarily of the sandy Goldenville Formation and overlying argillaceous Halifax Formation (Keppie, 2000). A transitional sequence between these two formations, known as the Halifax-Goldenville Transition Zone (GHT), has variable thickness up to 1 km and is characterized by Mn-rich rocks. Although gold appears to occur throughout the entire succession, a high proportion of the gold districts lie (1) at, or near the GHT boundary, (2) ~2 km below the boundary and (3) ~4 km below the boundary (Malcolm, 1929).

Within individual deposits, the host rocks display large, distal to proximal, alteration zones, characterized by silicic bleaching, carbonate, sericite and sulphide zones, respectively. Although new alteration mineralogy partly reflects the regional metamorphism, it also overprints regional metamorphic minerals. All the alteration minerals are present in the mined and milled auriferous lodes; therefore, it is important to characterize the trace element content and mineralogy of these alteration assemblages to better understand the speciation of elements in the tailings.

The Meguma Group meta-sediments are conformably overlain by mixed Silurian sedimentary and volcanic rocks. These strata were deformed into variably plunging, east-west folds during the Devonian Acadian Orogeny and metamorphosed at greenschist to amphibolite facies ca. 400 Ma. They were subsequently intruded by late Devonian (ca. 375 Ma) per-aluminous granitoid plutons.

Field observations and Re-Os dating from several gold districts reveal that there are two ages of sulphide mineralization (~408 Ma and ~370 Ma; Morelli *et al.*, 2003). Younger brittle-ductile shear deformation has overprinted the lode mineralization and associated host rocks throughout the Meguma Terrane.

Previous Geochemical Sampling Programs

During the past several decades, Environment Canada has completed several site specific multi-media sampling programs designed to investigate the impact of toxic metals and metalloids associated with former gold districts in the Meguma Terrane (Eaton, 1978; Mudroch and Clair, 1986; Wong *et al.*, 1999, 2002). Although these studies identified elevated concentrations of many elements in tailings, stream sediments, surface waters and lake sediments, the results are not interpreted within the context of the naturally elevated background levels expected in these mineralized areas. The speciation of metals and

Figure 1. Location of the ten gold districts selected for sampling and analysis in this study. All districts selected lie in the Halifax and Goldenville formations of southern Nova Scotia (Meguma Zone).

metalloids was also not investigated in detail, which is essential for assessing the risks associated with these contaminated sites.

The Meguma Terrane has been extensively mapped and sampled by NSDNR and the Geological Survey of Canada, with numerous regional geochemical surveys including till (Stea and Fowler, 1979, 1981), lake sediment (Bingley and Richardson, 1978; Richardson and Bingley, 1980), and vegetation surveys including balsam fir twigs and red spruce bark (Dunn *et al.*, 1989, 1992, 1994). Detailed multi-media orientation surveys are also available (Coker *et al.*, 1988).

Additional regional geochemical surveys have also been completed by numerous exploration companies in their search for gold, tin, tungsten and other commodities. These data are accessible from company-filed assessment reports available through the NSDNR library in Halifax, Nova Scotia. For example, one of the most comprehensive industry-based regional geochemical surveys was an extensive helicopter-assisted regional soil and till sampling program over the Meguma Group metasediments during 1986, 1987 and 1988 completed by Seabright Resources (Woodman *et al.*, 1994).

Methodology

Introduction

During the 2003 field season, a total of 50 humus, 50 soil and 50 till samples were collected from ten

past-producing gold districts: Leipsigate, North Brookfield, Whiteburn, Mount Uniacke, South Rawdon, Lake Catcha, Mooseland, Dufferin (Salmon River), Lower Seal Harbour and Upper Seal Harbour (Fig. 1).

For the humus/soil/till sampling program, a review of the local (1) ice flow history, (2) bedrock stratigraphy, (3) bedrock structure, (4) vein orientation and (5) mining development, including the location of tailings ponds and mill structures for each district, was undertaken prior to sampling. Sample sites were carefully chosen to provide (1) a broad aerial distribution of sample sites over each gold district, (2) representative coverage of the major surficial units within the study area, (3) representative coverage of the major lithologic units within the study area and (4) easy access by taking advantage of pre-existing roads. Most samples were collected along approximately NW-SE to N-S lines utilizing existing roads and/or traverse lines through the woods.

At each sample site, detailed field descriptions including observations on till type, colour and texture were recorded. Sample sites were geo-referenced to the Universal Transverse Mercator (UTM) grid (NAD 27) with a GARMIN GPS 12 using the averaging function. Each sample site was photographed for future reference.

In addition to the humus, soil and till, samples of bedrock waste material and bulk samples of tailings were collected to establish background trace element levels and for mineralogical examination. A total of 59 bedrock samples (2-10 kg each) and 55 bulk tailing samples (~5 kg each) were collected from the sites listed above, and from the Montague and Molega districts.

Field Sampling Methodology

A-horizon humus samples were collected, in general, simply by pulling off the live, moss-covered forest floor and collecting the black, decaying humus material by hand. Generally, the A-horizon was relatively thin (<5 cm). Pebbles and soil attached to the humus were shaken out of the sample and any living plant matter was also selectively removed prior to placement into a Kraft bag. Approximately 300 g of humus were collected from each site from an average sampling depth of 5 cm.

B-horizon soil samples were collected at each site by shovel and/or auger from an average sampling depth of 20 cm. Approximately 500 g of soil were collected from each site and placed into Kraft sample bags for future geochemical analysis. Visible organic material was selectively removed prior to placing the sample in the bag.

The C-horizon till samples were collected by shovel and/or auger from small hand-dug pits with an average sampling depth of 75 cm. Approximately 500 g of till were collected from each site and placed into Kraft sample bags for geochemical analysis. In addition to the samples placed in Kraft sample bags, approximately 4 kg of till were collected from each site and placed into 4 mil plastic bags for geochemical analysis. Once again, all visible organic material was removed from the sample prior to placement into the plastic bags, as were pebbles >4 cm in length.

Bedrock samples representative of all the major rock types were collected from each of the gold districts examined. These consisted of 1-5 kg samples collected from the waste piles surrounding the various shafts and mill sites, which should be representative of the ore and associated gangue material that was crushed and discarded into the tailings. The major rock types included within the sample suite were quartz veins, meta-greywacke, meta-siltstone and slate. An effort was made to include all the altered (carbonitized, sulphidized, sericitized and silicified) equivalents of the ore-bearing rocks.

Two or more bulk tailings samples were collected from each district in an attempt to give a preliminary indication of proximal verses distal distribution of minerals and elements relative to the milling facilities. If more than one mill structure was present within a single district, then one or more samples were collected depending on the areal distribution and thickness of the tailings. At each sample site a hole ranging in diameter up to 1 m was dug to a depth ranging from 30 to 200 cm. With rare exception, the water table was

encountered in all holes. At each site a composite sample was collected consisting of tailings material from top to bottom of the hole.

Laboratory Preparation and Analytical Methodology

At the time of writing, all humus, soil and till samples were in the final stages of preparation at DalTech Minerals Engineering Centre (Dalhousie University) in Halifax. All samples were air dried to a maximum drying temperature of 30°C to minimize loss of volatile elements such as mercury.

Three vials of <2000 µm and one vial of <63 µm were prepared for each medium of humus, soil and till. Humus, soil and till samples will be analyzed for Au-Hg, multi-element analysis (ICP-MS) and organic content. Heavy mineral concentrates (HMC) for microscopic examination and mineralogical identification were prepared from the 4 kg till samples collected from the Dufferin Gold District using a combination of a Wifley table and heavy liquid separation. The >2 mm size fraction was sieved, washed and bagged for future lithologic identification.

Rocks were crushed in a jaw crusher and pulverized with ring and puck to <105 µm and will be analyzed for Au-Hg and multi-element geochemistry. Selected samples from each district were prepared for polished thin sections at Vancouver Petrographics and pulverizing at DalTech for later whole-rock geochemistry. Arsenopyrite crystals up to 10 mm in size (to be inspected using a binocular microscope for the presence of gold, silver and cinnabar) were chipped from rock samples collected from waste rock dumps from the Dufferin Gold District.

Each bulk tailings sample was dried at a maximum drying temperature of 35°C and a split of four vials was separated. One vial was used for mineral identification, two vials were used for further pulverizing and whole-rock geochemistry, and the remaining vial was archived. The remainder of the bulk sample was processed for heavy minerals using a Wifley table at DalTech's Minerals Engineering Centre. These concentrates were retained for subsequent microscopic examination and microprobe chemistry.

Quality Assurance/Quality Control

A number of quality assurance/quality control (QA/QC) measures were incorporated into the sampling program and the preparation and analytical procedures to ensure the highest confidence in the quality of the data.

In the field, all personnel were trained with respect to standard sampling procedures and the acquisition of necessary site description information. Multiple sources of contamination were expected from historical gold mining operations (e.g. mill emissions, windblown tailings) and all identifiable sources were noted when observed. Field duplicates to test for site variance were not collected during the reconnaissance-level fieldwork in 2003.

All samples were kept out of direct sunlight in order to minimize the loss of volatile elements such as mercury. Photographs of most sample sites plus representative views of each gold district were taken for future reference.

Certified and in-house reference materials and preparation splits will be routinely submitted with all batches. All the humus, soil and till samples collected from the Dufferin Gold District, representing 10% of all the humus, soil and till samples, will be analyzed for Hg-As-Au at two laboratories as a check against inter-laboratory variance. Extra vials of sieved material were retained for future reference.

Results

Analytical results are pending for all samples. It is anticipated that analysis will take place early in 2004.

Discussion of Field Observations

In general, where the overburden profile is thin (<50 cm over bedrock), soil and till horizons are characterized by heavy oxidation, making it difficult to differentiate the boundary between B- and C-horizons based solely on colour. In areas where the till is relatively thin, the clast (and

matrix) composition strongly reflects the underlying lithology, indicating that the till is locally derived. The local nature of the till is further demonstrated by the angularity of the clasts, the presence of large boulders and the compact nature of the till. Greater that 90% of the till samples collected for this study were from the local Beaver River Till.

Lawrencetown Till, which was characterized by clasts reflective of a distal provenance, was locally encountered in areas of thicker overburden. Less than 10% of the till samples collected were Lawrencetown Till. Clasts tended to be rounded and consist of variable rock types that include but are not limited to pink granite, diorite, red and grey siltstone, and mafic volcanics. The ochre red colour of the Lawrencetown Till often made it difficult to differentiate the B soil from the C till horizon. Although the boundary was recognizable, the colour change between the B- and C-horizon was very subtle.

In oxidizing environments, a typical tailings profile consisted of an upper stratified, light grey-brown to yellow-brown oxidized portion, underlain by a thin (~10 cm) yellow to orange hardpan layer, which was in turn underlain by grey un-oxidized tailings. At several sample sites, a thin peat horizon representing two distinct periods of mining activity separated a lowermost, grey, un-oxidized tailings layer from an overlying, grey, un-oxidized tailings layer. At these sites, an effort was make to collect each of the un-oxidized tailings separately. Un-oxidized tailings were always encountered below the water table, and in areas where vegetative cover limited oxygen penetration.

Most samples collected in the field were of excellent quality. However, at a few sites, the humus layers may have been very thin and some mineral soil may have been introduced into the sample, some soil horizons were relatively organic-rich, and some till sites were highly oxidized. Locally, particularly around the former mill sites, the presence of tailings was often noted and efforts were made to relocate soil sampling sites to less disturbed areas.

Anthropogenic effects were not limited to the presence of tailings. Waste rock piles, bush roads and building foundations were common to each district sampled. Locally, drill steel, stamp mill pads, assay equipment and related mining artifacts were observed. Recent anthropogenic effects include household and commercial garbage dumped down mine shafts, filling trenches as well as sporadically strewn along bush roads and/or piled in clearings.

Summary

Ten past-producing Nova Scotia gold districts were carefully selected for multi-media geochemical sampling after all districts were ranked according to their production history, use of mercury during the gold recovery process, and the known extent of tailings at each site. Humus, soil, till, rock and tailings samples were collected to determine their multi-elemental content. Analytical results are pending.

Field observations in 2003 show that most sites contain large volumes of unconfined tailings, which are generally located in low-lying areas (e.g. swamps, streams) downslope of the stamp mill sites. In some districts (e.g. Lower Seal Harbour, Dufferin) the tailings have been transported significant distances (>2 km) off-site by local drainage. At most sites, the tailings are very overgrown and often difficult to recognize; however, some tailings areas are being actively reworked by human activities (gold panning, off-road vehicle usage).

Once all the analytical results are received, a mass balance calculation will be completed to determine the relative volumes of metals that characterize each major lithology. It is anticipated that the natural levels of toxic elements will be distinguished from anthropogenic levels within the various environmental media at each mine site.

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Reclamation of the Irish Cove Limestone Quarry (NTS 11F/15), Richmond County

D. B. Hopper and F. J. Bonner

Introduction

The reclamation of the Irish Cove Quarry demonstrates how planned reclamation with community input can restore the land to a sustainable natural environment, free from safety hazards and long-term liabilities. This project also demonstrates land-use efficiency, wherein mining is part of a sequence of usage, preceded by hunting and traditional use, settlement, farming and forestry. Each sequence provided economic benefits to the community without jeopardizing the ability of the land to provide for future generations.

Property Description

The Irish Cove limestone quarry (Fig. 1) is located in one of the most scenic areas of Cape Breton Island. The quarry property lies on Crown land, adjacent to the village of Irish Cove on the eastern shore of Bras d'Or Lake, about 35 km north of St. Peter's and 50 km south of Sydney. The 65 ha property is composed of four adjacent Crown land parcels and 790 m of waterfront along the edge of Bras d'Or Lake. Private land holdings lie to the east and west sides of the property and Highway 4 defines the southern boundary. The Crown land block continues on the other side of Highway 4, uphill and upstream within the catchment area of Irish Cove Brook. A scenic look-off, located along Highway 4 and near the summit of MacLeod's Hill, offers a spectacular view over Bras d'Or Lake, the East Bay Hills and the village of Irish Cove. Prior to quarrying the land consisted of a rolling, pastoral landscape with northeast-facing slopes, gently dipping toward the lake. The property was occupied by small farms with cleared pasture bounded by regenerated forest.

The quarry operation excavated part of a northeast-facing slope between the lower flanks of the East Bay Hills and the Bras d'Or Lake shore (Fig. 2). The original contours were altered to yield a more roughened terrain with steep highwalls surrounded by hummocky areas formed by piles of topsoil and overburden. Most of the overburden is revegetating naturally with pioneer and other invasive species of grasses, legumes, forbs and low shrubs. The most visually dominant elements on the property are large stockpiles of light-grey, crushed limestone, which lie immediately adjacent to Irish Cove Brook. From the far west to southwest side of the property the land is mostly tree covered and was not affected by the quarry operation. In the late 1990s an illegal clear cut occurred close to the upper section of the quarry highwalls. In the northern area an old section of Route 4 runs parallel to the shoreline, which was used for the quarry. The Irish Cove bypass was constructed in the 1970s, and runs down MacLeod's Hill and curves around the quarry and Irish Cove village. Two settling ponds located close to the lake shore are contained by an embankment dam. One is a small pond which contains wetland vegetation, while the other is dry most of the year, except in the wetter months during spring.

The quarried area contains debris, stockpiles of limestone, exposed cliffs, and steep overburden mounds which all provide hazards to public safety. The most disturbed portion of the site occurs in the area containing the steep quarry walls (Fig. 2, middle ground, right of centre) and the stockpile area lying adjacent to Irish Cove Brook (Fig. 2, middle ground left of centre). The brook and riparian area has been impacted by the former operation and continues to be stressed from the crushed limestone stockpiles along the west bank, which erode into the stream. The occupation of the stockpiles on the riparian zone continues to inhibit revegation.

The quarry landscape spoils the area's scenic and ecological values. The excavated terrain, lack of revegetation, size, height and light hue of the stockpiles all contribute to an unsightly appearance

Hopper, D. B. and Bonner, F. J. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 15-24.

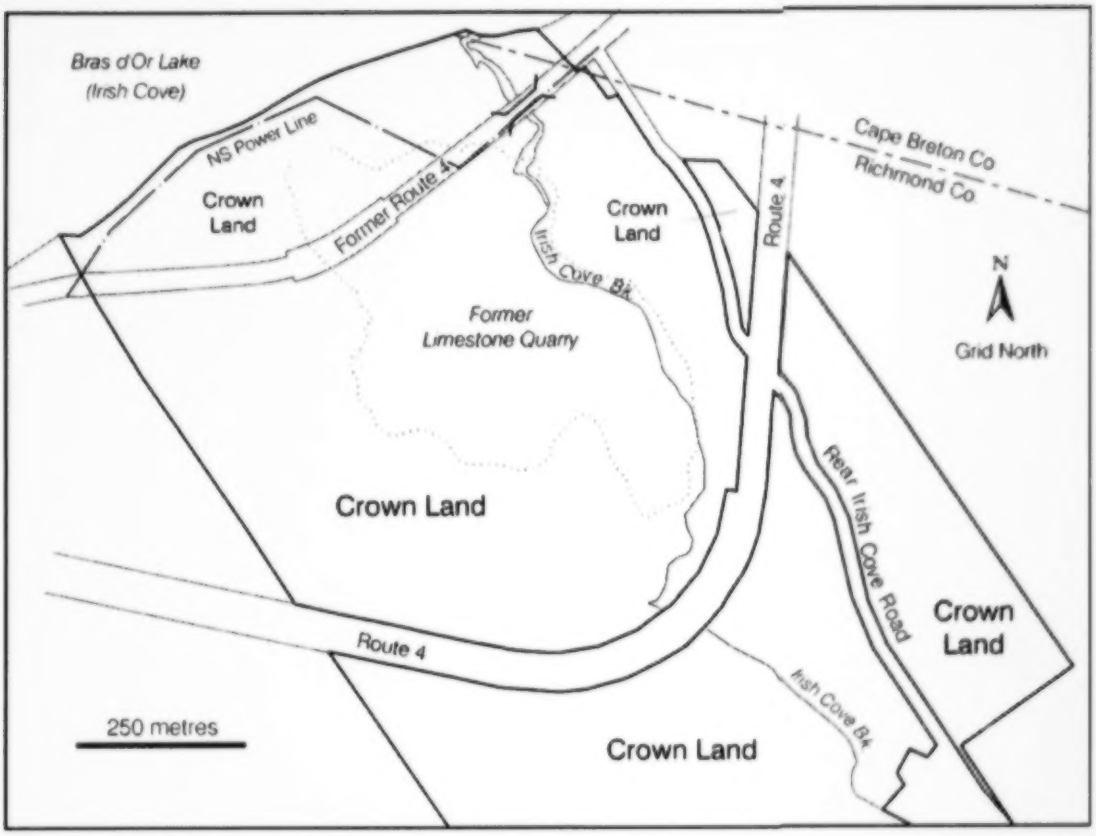

Figure 1. Map of the Irish Cove Limestone Quarry property

that is conspicuous from the lake and Highway 4. Areas where topsoil has been removed for quarrying, and other areas covered with deep layers of limestone gravel, provide unsuitable conditions for substantial regeneration of vegetation. The combined effect of landscaping and revegetating the site will greatly improve the local ecosystem, habitat and scenic values.

Reclamation Planning

In 1988 Scotia Limestone Limited provided the province with a Letter of Guarantee committing the owner to reclaim the site. This obligation was acquired by SYSCO upon the purchase of the property from Scotia Limestone. After the quarry closed the property was left in an abandoned state, including a stockpile of over 100 000 tonnes of crushed, screened limestone. The land was reconveyed to the Crown in 1993 and DNR made several unsuccessful attempts to sell the stockpiled limestone to augment the cost of reclamation. As the site remained untouched for over 12 years, the residents of Irish Cove and nearby Johnstown registered concern that the property was unsafe and unsightly. The department turned to investigating options for reclamation, which led to an allocation from the SYSCO fund for reclaiming former SYSCO quarries.

In June 2001, DNR staff prepared a draft reclamation plan entitled *Irish Cove Limestone Quarry: A Conceptual Plan for Reclamation and Site Development*. The report referred to DNR's Integrated Resource Management (IRM) assessment for the Irish Cove Crown block, noting the presence of a mix of resource, recreational and ecological values including high scenic values,

Figure 2. Photo of the Irish Cove Quarry (looking south) circa 1992.

significant wildlife values and "a rare opportunity to provide public access to the Bras d'Or Lake shore." This suggested that the property's natural assets provide an opportunity to redevelop the site for nature conservation and passive recreational use (Fig. 3).

Issues, Objectives and Options

The department's foremost concern was to improve the condition of the property by reducing public safety hazards and improving environmental quality. Central issues and recommended actions (Table 1) were determined by DNR staff and a working group which consisted of local residents and representatives from other agencies.

Safety objectives aim to reduce the severity of all slopes and high walls to an average grade ratio of 1:3. This is to reduce the hazards of steep terrain and provide adequate slopes for revegetation. The piles are relatively high and steep, and tend to attract ATV and motorcycle riders. During winter the snow-covered slopes are popular for tobogganing, which has resulted in at least one known injury. One of the most important safety measures in this reclamation project is to move most (90%) of the stockpiled material back into the quarry for backfilling against highwalls. The remaining material will be used to cover and landscape the riparian zone. A former truck-loading ramp and drop-off presents a public hazard. The structure will be dismantled and disposed of with the other quarry debris. The remaining embankment is to be smoothed down and incorporated into the new landscaping.

Figure 3. Reclamation plan for the Irish Cove Quarry.

Table 1. Main issues and options determined for the Irish Cove Quarry property.

Primary Reclamation Issues		Post-reclamation options
Safety Issues	**Environmental Issues**	
Stockpiles	Quarry debris	Public access 'Geopark' and recreational area Nature Trail System Memorial Grove Nature conservation
High walls	Visual Impact	
Quarry debris	Stream and riparian zone habitat	
Loading ramp	Reduced habitat	
Embankment dam	Vegetation	
Wooden bridge	Topsoil and fill	
Abandoned well	ATV use	
ATV use		

Environmental objectives are directed at improving conditions for valued ecological components such as wildlife habitat and levels of biodiversity. Wildlife habitat will be improved through suitable revegetation techniques. Exposed areas will undergo hydroseeding and replantation to prevent erosion and runoff, and to aid revegetation. Hills and steep slopes will be recontoured to blend with the surrounding topography.

There is ample evidence of ATV use in different parts of the site. Tracks were observed on the stockpile slopes, on stream banks and along the settling pond embankment. To protect the investment made in reclamation, revegetation and stream restoration, signs will be posted prohibiting ATV and motorcycle use on the site. The ATV issue was discussed at reclamation planning meetings where community representatives indicated that they could play a part in increasing local awareness to help prevent ATV and motorcycle use on the property. This will be particularly important immediately after the site has been hydroseeded and in an early stage of revegetation. DNR regional wardens will be asked to include the Irish Cove property as part of their Crown land surveillance.

Post-reclamation Options

The initial proposal for post-reclamation redevelopment was for amenity use. A 'Geopark' and recreation area was proposed, which aimed at highlighting the geology, fossils, process of natural regeneration, stream restoration, vistas and access to the Bras d'Or Lake shore. Some development was suggested, including a picnic shelter, parking area and nature trail system with interpretive panels. The concept was presented by DNR staff to local residents at a public meeting in Johnstown in June 2001.

The community's reaction was generally positive; however, some residents expressed concern that a developed recreation area would produce increased traffic and parking along Lakeshore Drive in Irish Cove. DNR was asked to consider alternate access to the Geopark, although local residents expressed an interest in maintaining existing access across the brook at the end of Lakeshore Drive. The only alternate access point is a former skidder road ('woods' road) that runs off Highway 4 along the southern boundary. This is a short road that runs downhill from Highway 4 to the top of the quarry's high walls, then turns east and joins an old quarry road that leads downhill to the stockpile area next to the brook. The existing condition of the alternate route required considerable work and expense to upgrade to a two-lane road, plus the cost of developing a graded parking area. As the scale of development and further costs for alternate access were not accounted for in the original reclamation budget it was decided that the Geopark recreation area concept be replaced by a more general amenity solution for nature conservation and stream restoration.

Land Reclamation

Land reclamation began in September 2003 after the Department of Transportation and Public Works signed a contract with Harold Phillips and

Figure 4. Photo of the Irish Cove Quarry reclamation project (June 2004).

Son. Ltd., of Mira Gut. The preliminary work and site preparation included permitting, cleaning up the site and establishing sediment and erosion control structures (Fig. 4). Debris was removed such as truck parts, wooden structures, metal and plastic pipe, cable, tires, fuel drums, power lines, etc. Non-essential power poles and lines were disconnected and removed. The power poles were donated to the local community after residents expressed interest in acquiring them for holding lamps along a nearby cross-country ski trail. A drilled water well was inspected by Nova Scotia Department of Environment and Labour staff and later decommissioned.

Groundwork and Recontouring

All groundwork was carried out with material found onsite, particularly the stockpiled limestone. This material was located on the banks of the brook which impeded the stream's meandering ability and prevented the development of vegetation and wildlife habitat in the riparian zone. The material was moved away from the banks of the brook to provide at least a 25-30 m wide flood zone. The landscaping provided final contours to approximate a northeasterly aspect (dipping toward the lake and the brook) with a slope ratio of between 1:10 and 1:3.

Reclaiming Highwalls and Overburden

The quarry walls and steep overburden (areas 1, 2, 3 and 5 as shown on Fig. 3) lying above the crests of the walls were public safety hazards. The quarry walls located in Areas 1 and 2 were, by far, the

Figure 5. Photo of the Irish Cove Quarry highwalls before reclamation.

Figure 6. Quarry walls after reclamation and recontouring.

greatest danger to public safety with steep faces exceeding 10 m in some places (Fig. 5). Therefore, these areas were the top priority areas to be backfilled. The stockpiled limestone was moved back into the quarry as fill and ramped up against the walls to slopes of approximately 1:3 (Fig. 6). The northern and southern flanks of Area 4 (former quarry faces) also required limestone fill material to achieve the required 1:3 slope ratio.

The second issue is the acquisition of cover material. The quarry operation did not separate and stockpile the topsoil which leaves a mix of topsoil and overburden as the only source of growing medium for revegetation. Prior to quarrying the overburden was either "pushed" off the limestone or stockpiled in specific areas as shown in Figure 3. In some areas the overburden was originally 10-12 m thick and, therefore, the easiest method of removal was to simply push it to the perimeter of the workings. Over time, the quarry face advanced toward the perimeter resulting in steep, unstable overburden piles crowning the pit walls (Areas 2 and 3). Over time these slopes revegetated naturally with a dense growth of wild rose bushes, which provide the additional danger of obscuring the edges of the quarry walls.

After the stockpiled limestone was backfilled in Area 2 and 3, overburden at the crests of the pit walls was pushed back down on top of the limestone fill as a cover for revegetation. The new slope essentially creates a smooth surface from the base of the slope to the top where the overburden formally rested. Remnants of the pit walls that stood as a constant reminder of quarrying are now barely visible.

Grasses and shrubs flourish on all the overburden piles including small trees in some areas. Although the overburden in Areas 7, 8 and 10 was identified for cover material, it will be kept intact to preserve existing vegetation and reduce the overall disturbance of the site.

Revegetation

Once the ground conditions were suitable in the late spring of 2004, the revegetation process began (Fig. 7). This included the replantation of 185 small trees and shrubs and hydroseeding all uncovered areas. Revegetation aims to augment the gradual redevelopment of natural forest conditions in areas where quarry activity occurred. This will provide a necessary boost for local species diversity and the normal processes of plant succession, which is taking place from adjacent pockets of undisturbed vegetation. The undisturbed forest areas contain stands of white spruce, eastern hemlock and ash along with juvenile seedlings.

Wild rose, blackberry and raspberry bushes, white ash and alder form part of the existing shrub cover, which contributes nitrogen necessary for improving soil fertility. The selection of shrubs for transplantation was conducted by a vegetation specialist from Transportation and Public Works. The shrubs were extracted by machine and transplanted immediately. Areas where overburden slopes have been relandscaped with limestone fill and overburden have been seeded and fertilized by hydraulic seeding and manual methods of dispersal. The seed mix recipe is designed to attract wildlife. It contains creeping red fescue, birdsfoot trefoil, orchard grass, kentucky bluegrass, ,alsike and white clover. A layer of hay mulch was spread over the seed to retain moisture and minimize seed and soil loss from wind, rain and runoff.

Prior to reclamation DNR called for a survey of vascular plants growing on the property, which was conducted by Crompton and Stahevitch-Crompton in the fall of 2002. Their observations described a variety of plant communities in early succession throughout the site. The survey found the quarried areas to be arid, where the soils are shallow and depleted in nutrients and organic matter. The arid conditions are likely due to the lack of moisture-retaining organic matter and the rapid drainage capability of the underlying limestone. Most of the plants found are classified as abundant, common or occasional in abundance. Only a few species are regarded to be rare (such as hawkweed, sandwort, curled dock and woundwort hedge-nettle), which were found in areas undisturbed by quarrying or farming. Once the revegetation efforts have had four or five years to establish, a second plant survey should be done for a comparative analysis and to measure species diversity.

Figure 7. Photo of the reclamation project circa June 2004. Areas 2, 3 and 4 (background) are complete and seeded. Area 1 (middle ground) is used as a source of cover material for Areas 9 and 11 (former stock pile in foreground).

Stream Restoration

Irish Cove Brook and the riparian zone represent the most significant ecological components of the site, which provide a vital ecological link between the forested uplands and the marine environment of Bras d'Or Lake. The brook flows down the East Bay Hills in a northwesterly direction, and enters the property through a large culvert underneath Highway 4. Once through the culvert the flow is deflected sharply to the east and northeast and runs along the eastern edge of the property between a limestone escarpment and stockpile area (see Fig. 3). Several issues occur concerning aquatic habitat, including siltation, erosion, shallow water and greatly reduced cover due to a sparsely vegetated riparian zone. The stockpiles have significantly reduced the capacity for revegetation and habitat development in the riparian zone. The limestone gravel tends to drain moisture quickly and leaves the surface areas extremely arid and nutrient poor. The stockpiles also confine the stream, which prevents the development of a meandering pattern and deposition of nutrient-laden silt. Some stockpile slopes have spilled into the brook, which leads to local bank slumping and subsequent siltation of the stream bed and estuary channel.

The main objectives for restoring Irish Cove Brook and the riparian zone include: improving aquatic habitat for salmon and trout, producing higher species diversity, increasing vegetation cover, improving stream-bed morphology, and providing a net gain in fish habitat.

DNR asked for assistance with stream restoration planning from the provincial Department of Fisheries and Aquaculture (DOFA)

and the federal Inland Water Habitat Management Division at Bedford Institute of Oceanography. DOFA staff conducted a stream assessment in July 2003 to evaluate and monitor physical and biological stream conditions such as water quality indicators, fish species, water temperature, substrate composition, canopy and shade cover, velocity and water depth. These data will provide a benchmark for future surveys after the reclamation and stream work is complete. In June and August 2003, DFO staff visited the site to assess and develop a layout design for in-stream structures. This involved measuring and marking locations for structures (either digger logs[1] or rock ledges) and determining the need for additional structures. In-stream structures are used to re-establish the natural meander of a stream and to develop pools and gravel beds that are suitable for spawning. As the water flows over the log (or rock sill), fine materials are removed and the remaining gravel is sorted, thus creating a preferred habitat for fish. These structures also help raise the oxygen content of the water, and the boulder and cobble ramp provides habitat for aquatic insects on which fish feed.

A restored riparian zone will help to reduce pollutants in surface runoff, help control surface and bank erosion, provide a shaded microclimate that keeps the water cool for stream biota, provide fish habitat in the form of undercut banks with the "ceiling" held together by roots of woody vegetation, provide organic material for stream biota, provide habitat for terrestrial insects, and travel corridors for animals. Once the stockpile material has been removed the remaining landscape will be graded to a gentle slope and revegetated. Bioengineering techniques such as wattling can be used to boost the success rate of revegetation efforts and help to reduce erosion, especially along the stream banks.

Irish Cove Brook has the potential to function once again as an anadromous stream, similar to other streams flowing into the Bras d'Or Lake which contain trout and salmon. After the reclamation work is complete in 2004, it is hoped that the work toward stream restoration will commence in the summer months next year. This phase of the project will rely mostly on the efforts of interested community organizations and local support to raise the necessary funding. Meetings have already occurred between DNR staff, Strait-Highlands Regional Development Agency, Johnstown Community Development Cooperative, the Richmond Fish and Wildlife Association, local residents and others. All are optimistic that this phase of the project will be accomplished. This will complete the task of reclaiming the Irish Cove Quarry and provides Nova Scotia with a successful demonstration of how sustainable development principles can be applied to mining.

[1]Digger log structures consist of hardwood logs secured to the streambed, at a 30-degree angle to the bank, using rebar. Boulders and cobbles are removed from the downstream side of the log and placed upstream to create a ramp, causing the water to cascade over the log.

Geological Report on the Early Stages of Development of the Mooseland Gold District (NTS 11D/15), Halifax County

R. J. Horne, G. Covey[1] and C. Albert[1]

Introduction

Discovery of gold at Mooseland was first documented in 1858 and gold was mined intermittently between 1863 and 1934, with total recorded production of 3,865 oz. (Bates, 1987). Sporadic exploration has continued at Mooseland: the most serious effort was made by Acadia Minerals and Hecla Mining in the late 1980s, with the drilling of 135 diamond-drill holes and the sinking of a 400 foot shaft (e.g. Covey, 1988). In 2003 Azure Resources Corporation optioned the Mooseland property and in late 2003 and early 2004 the company established a decline and carried out bulk sampling of the Little North and Cummings belts. This report describes surface mapping in the Mooseland District, and the geology of the underground development completed by Azure Resources.

Location and Geological Setting

The Mooseland Gold District is one of many past-producing Meguma gold deposits occurring in the Meguma Terrane (Fig. 1a). The district straddles the Mooseland Road approximately 18 km north of Highway 7 (Fig. 1b). Historical workings occur in the area between the Musquodoboit Batholith to the west and the Tangier River Fault to the east, and were mainly restricted to the south limb of the Mooseland Anticline (West Zone, Figs. 1, 2). Exploration diamond-drilling by Acadia Minerals in the late 1980s intersected auriferous veins on the east side of the Tangier Fault. The veins are thought to represent the faulted extension of the main Mooseland vein array (East Zone, Fig. 2).

The vein system at Mooseland consists of mainly stratabound veins in slate or metasiltstone intervals of the metasandstone-dominated Goldenville Formation. Where two or more distinct veins occur within a slate interval, the term "belt" is used to refer to the stratigraphic interval hosting those veins. Stratigraphy and related structure provide the principal framework for the stratabound veins and, therefore, a detailed cross-section is presented to evaluate the vein system. Although the district extends westward to the Musquodoboit Batholith, cross-cutting relations between the veins and the granite, or associated contact metamorphism, have not been established.

A decline was initiated in 2003 on the north limb of the Mooseland Anticline, east of the Mooseland Road (Fig. 2). The decline trends west-southwest, crossing the fold hinge at a small angle, and then south-southeast, cutting perpendicular to the hinge through the south limb, where it exposes the Bismark, Irving, Little North and Cummings belts (inset, Fig. 2). Drifts were developed east and west of the decline on the Little North and Cummings belts for the purpose of obtaining bulk samples. The underground exposures have been utilized to establish a cross-section of the development (Fig. 3) and to evaluate the three-dimensional character of the Little North and Cummings belts.

Structure

At this deposit, the Mooseland Anticline defines a steep, tight (inter-limb angle of ~35°) chevron structure (Fig. 3b). A well developed, fine continuous cleavage in the slate or metasiltstone is steeply dipping, with a small angle to bedding,

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Horne, R. J., Covey, G. and Albert, C. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 25-39.

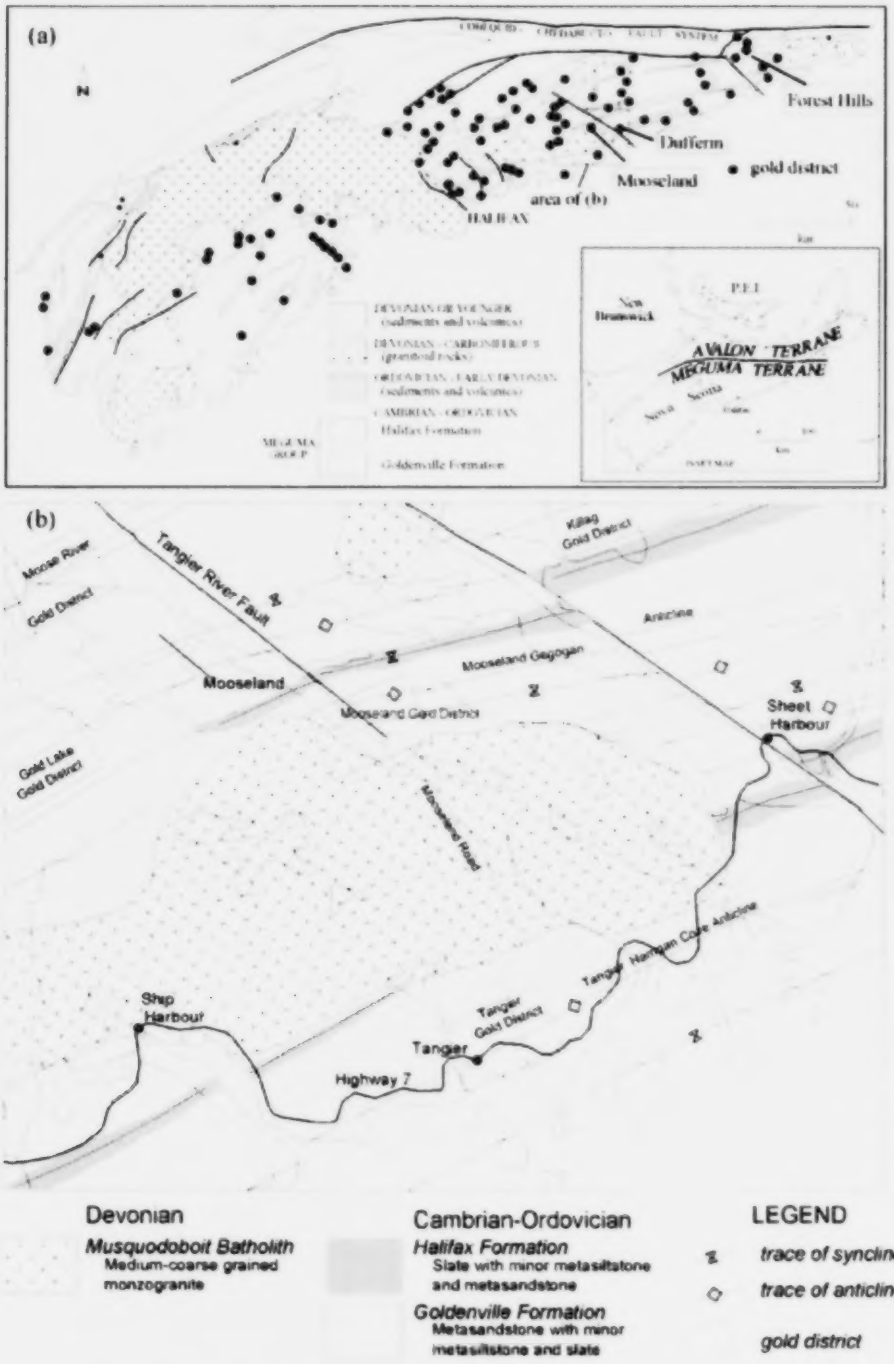


Figure 1. (a) Simplified geological map of the Meguma Terrane showing the location of the Mooseland and other Meguma gold districts. (b) Map showing the geological setting of the of the Mooseland Gold District.

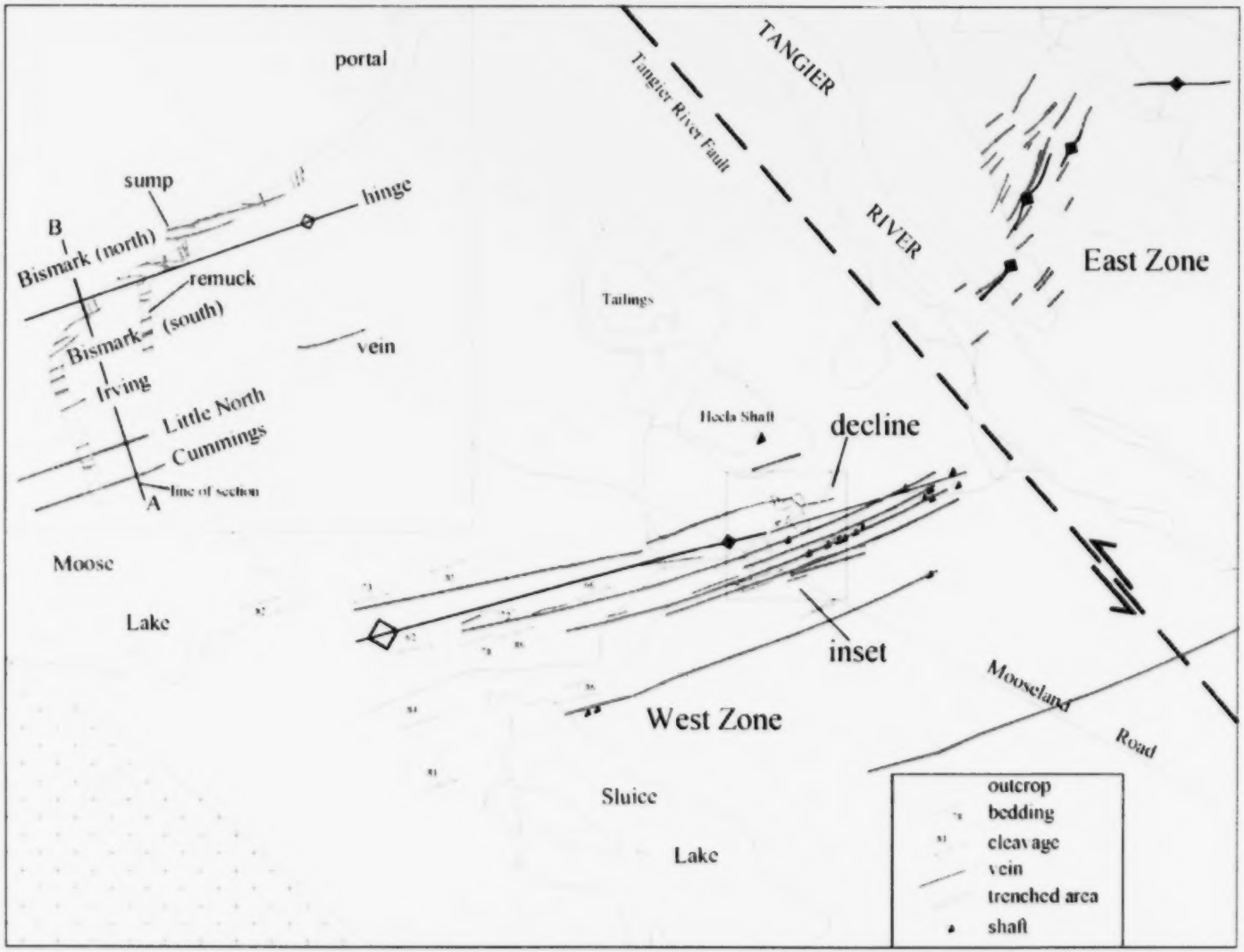


Figure 2. Geological map of the Mooseland Gold District showing the general geology, areas of previous mining and the location of current underground development conducted by Azure Resources. Inset map shows the map projection of current (early 2004) underground development.

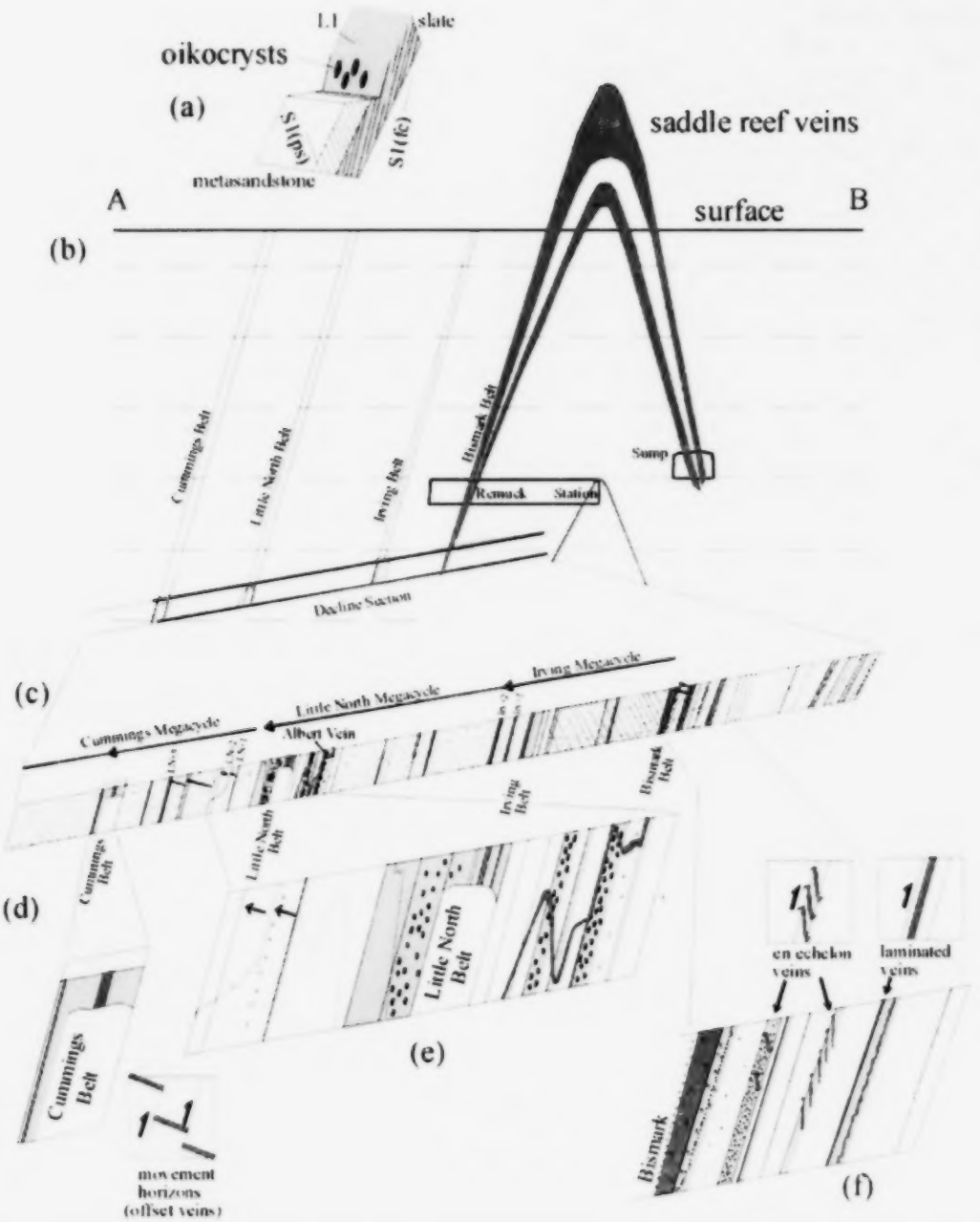


Figure 3. Cross section and detailed section of the Mooseland Anticline constructed from underground development. (a) Schematic diagram showing structural elements related to the Mooseland Anticline; L_1=bedding-cleavage intersection; $S_{1(fc)}$=fine continuous cleavage in slate; $S_{1(ps)}$=spaced pressure solution cleavage in metasandstone. (b) General cross section of the underground development showing the projected workings and the principal mineralized belts. See line of section A-B in inset of Figure 2 for location of section. (c) Detailed section for the lower part of the decline. (d) Detailed section of the Cummings Belt. (e) Detailed section of the Little North Belt. (f) Detailed section of the Bismark Belt.

whereas a well developed, spaced, pressure solution cleavage in the metasandstone is generally observed at a moderate angle to bedding (Figs. 3a, 4b, 5a). Faribault (1899a) indicated that the anticline formed a dome structure centred west of the Mooseland Road; however, bedding-cleavage intersection lineations and fold hinges invariably plunge slightly to the east (Fig. 4b). There is a notable thickening in the hinge zone, typical of chevron style folds, which is likely accommodated by flow of metasiltstone and slate, and by saddle reef formation.

Distinct elongate mineral aggregates, called oikocrysts (Kontak *et al.*, 1990), which define a pronounced mineral lineation, are ubiquitous in dark slate-metasiltstone intervals throughout the Mooseland district and have been previously described by Melvin (1987) and Kontak *et al.* (1990). These mineral aggregates are typically pencil-shaped, with a long axis measuring 1-2 cm and a width of 1-2 mm (Fig. 5b). The aggregates occur within the cleavage plane and their long axes are perpendicular to the fold axis (bedding-cleavage intersection lineation; Figs. 4b, 5b), and are interpreted to reflect fold-related strain. Oikocrysts trend steeply to the west (Fig. 4b), consistent with east-plunging bedding-cleavage lineations, supporting an east-plunging fold axis. Quartz pressure shadows occurring on sulphide minerals, most notably arsenopyrite, also define a down-dip lineation, likely recording the same fold-related strain as the oikocrysts.

A crenulation cleavage, S_{2C}, is locally developed, crenulating the fine continuous S_1 cleavage in slate and metasiltstone. The crenulation is shallow dipping, and the intersection with S_1, or bedding, has a shallow plunge to the east. This crenulation cleavage is restricted to bedding-parallel zones adjacent to bedding-concordant veins or movement horizons. A similar crenulation noted in the Waverly-Halifax airport area, including the Oldham Gold District, was interpreted to reflect shear resulting form flexural-slip folding (Horne *et al.*, 1997). A mineral fabric defined by biotite, S_{2M}, is recognized in some thin sections. This fabric is most commonly observed in biotite forming oikocrysts, but is locally developed in the matrix (Fig. 5c). This fabric appears to be parallel to the crenulation cleavage, and may reflect mineral growth recording the same strain as the crenulation cleavage (S_{2C}).

Stratigraphy

As with most Meguma lode gold deposits, stratigraphy plays an important role in the development and distribution of veins, with many occurring as bedding-concordant veins in metasiltstone and slate intervals. These veins occupy structures that record flexural-shear strain,

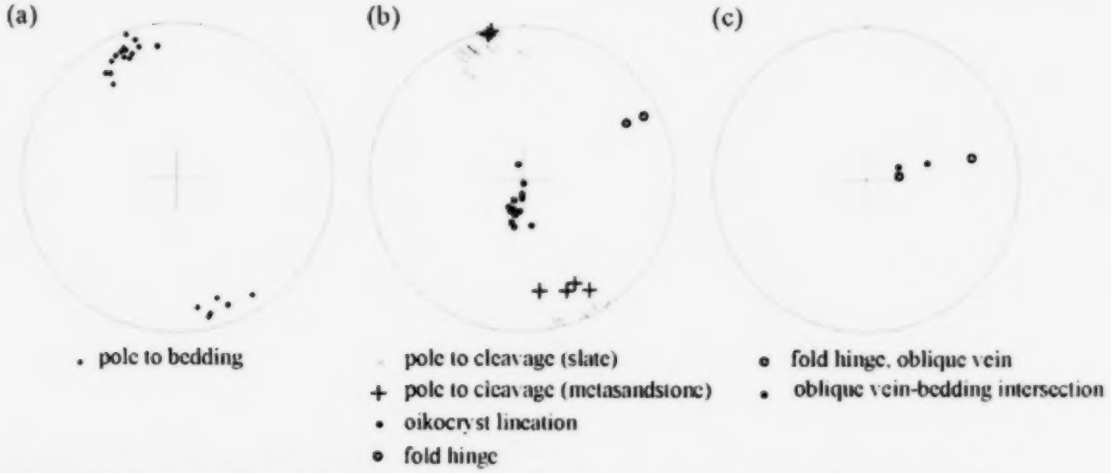


Figure 4. Lower hemisphere equal area stereoplots of structural data from the Mooseland Gold District; (a) and (b) present data for the Mooseland Anticline and include surface and underground data; (c) represents data for the oblique veins of the Little North Belt.

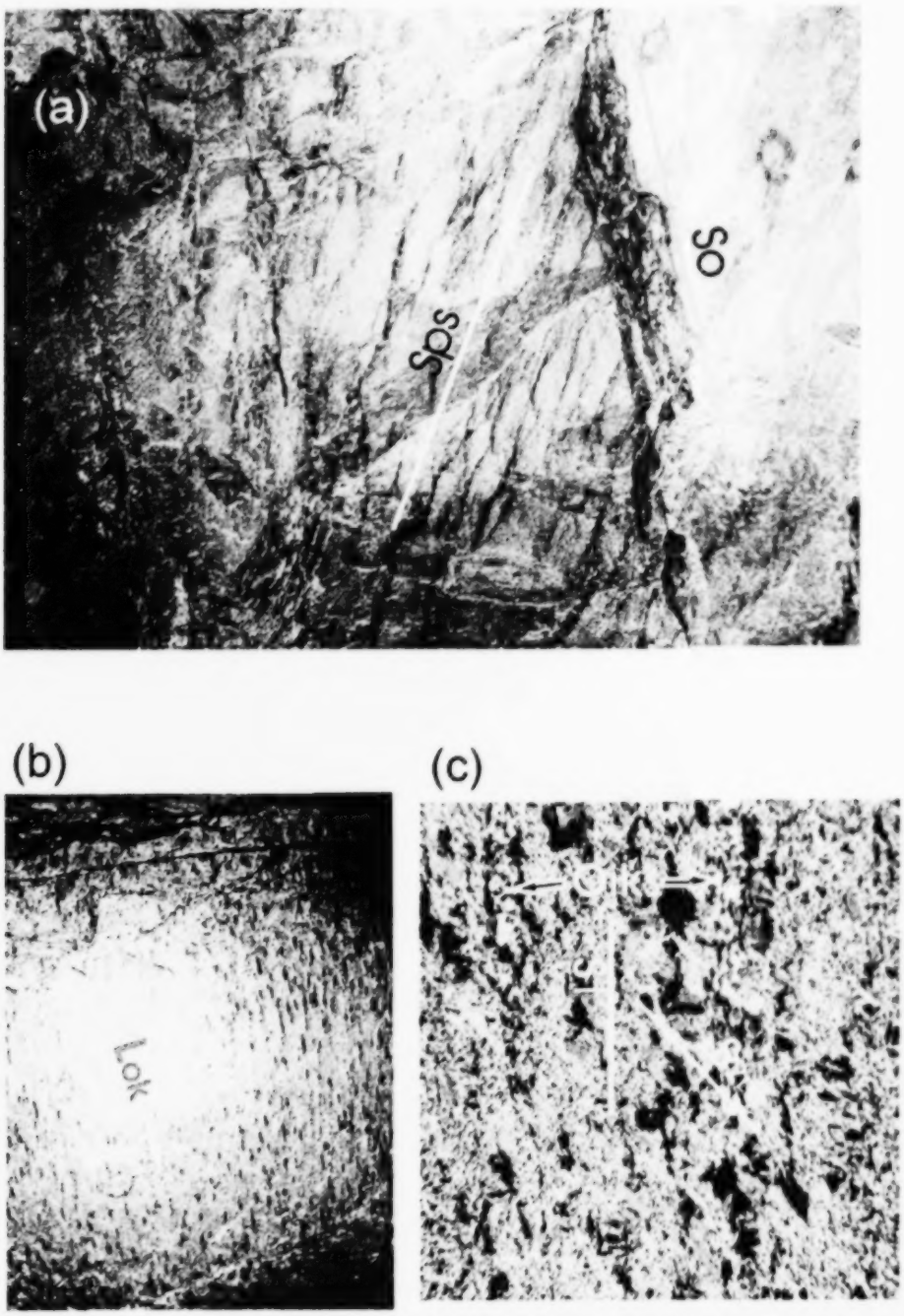
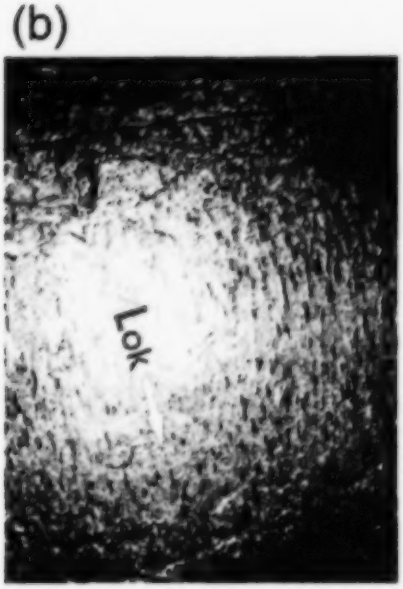
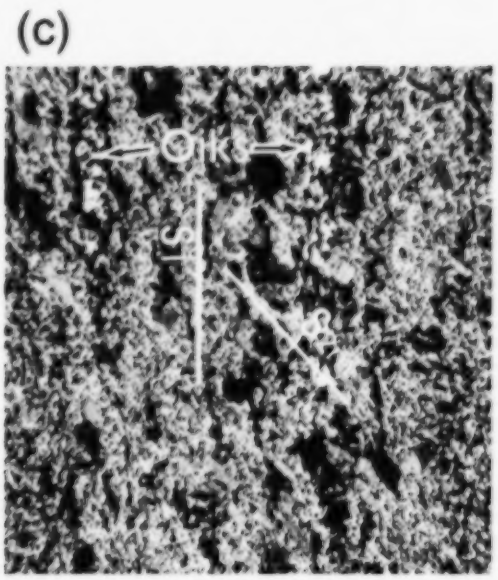


Figure 5. (a) Photograph of altered and cleaved metasandstone; S_{ps} = well developed spaced pressure solution cleavage; S_o = bedding. (b) Photograph of cleavage plane in metasiltstone with abundant oikocrysts defining a lineation perpendicular to the bedding-cleavage intersection (L_1). (c) Microphotograph of metasiltstone showing a mineral fabric defined by aligned biotite (S_{2m}) oblique to the principal cleavage (S_1). Section cut perpendicular to cleavage and parallel to the oikocryst lineation; Oiks=oikocrysts.





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which is focused in the incompetent units during folding; therefore, the distribution of bedding-concordant veins should be evaluated in the context of stratigraphy. Intense alteration at the Mooseland deposit often makes it difficult to distinguish metasiltstone from slate, so these units have been generally grouped; exceptions include designation of distinct black slate. Stratigraphy is characterized by fining-upward cycles, dominated by metasandstone at the base and fining upward into relatively thin metasiltstone and/or slate intervals at the top. Contacts within cycles are gradational; however, contacts between cycles are usually sharp (i.e. sharp contact between the slate at the top of a cycle and the metasandstone at the base of the overlying cycle). The thickness of cycles ranges from several metres to less than 1 m.

There is at least an apparent large-scale systematic stratigraphic variation, characterized by thick intervals of metasandstone-dominated cycles with only very minor metasiltstone-slate, and thinner intervals dominated by relatively thin cycles where slate-metasiltstone represent larger parts of individual cycles. This systematic variation may represent large-scale sedimentary cycles (megacycles) which, like individual cycles, are characterized by thick metasandstone-dominated intervals overlain by thinner intervals with significant metasiltstone-slate (Fig. 3c). Although minor bedding-concordant veins occur within thin metasiltstone layers at the tops of individual thick metasandstone-dominated cycles, the main bedding-concordant veins occur within the intervals of relatively thin cycles at the top of megacycles and represent the veined and mineralized "belts". For reference, the identified megacycles are named for the belt that is located at the top of the cycle (e.g. Little North Megacycle; Fig. 3c). The apparent large-scale cycles that control the distribution of intervals with considerable fine-grained rocks appear to have a fairly regular distribution, accounting for the systematic distribution of belts (Fig. 3b).

Veins - Belts

Introduction

As outlined above, the majority of veins observed in this section are bedding-concordant, occurring in metasiltstone and slate at the tops of cycles. Several bedding-concordant vein types occur, including massive bedding-parallel, laminated bedding-parallel, en echelon vein arrays, and saddle reef veins. In addition to general classification, individual veins have distinct mineralogical and textural characteristics.

Below the Bismark

The Bismark Belt is structurally the lowest belt of the four so far exposed in the Mooseland District. However, development below the Bismark Belt has encountered several additional minor bedding-concordant veins. Although not currently of economic interest, these veins are important to understanding the Mooseland vein array and, therefore, these various vein types are discussed here.

En Echelon Veins

Two sets of bedding-concordant en echelon vein arrays occur immediately below the Bismark vein, with exposures located in the decline and in the remuck station (Figs. 3f, 6a). Individual veins have a sigmoidal shape and crosscut metasiltstone intervals, with their ends pinned in metasandstone. The intersection of these veins with bedding is parallel to the fold hinge, and they record a shear sense consistent with flexural shear: movement of the structurally higher beds toward the hinge. En echelon bedding-concordant vein arrays are common in Meguma lode gold deposits and a more detailed explanation of their formation is provided in Horne and Jodrey (2001).

Laminated Bedding-parallel Veins

A laminated bedding-parallel vein occurs below the en echelon veins mentioned above, exposed in the remuck station and the decline. This vein is ~3 cm thick and is characterized by a distinct laminated ribbon texture (Fig. 6b), similar to "laminated" bedding-parallel veins documented in other Meguma lode gold deposits (e.g. Smith and Kontak, 1988a). This vein is persistent along strike in diamond-drill holes and consistently yields elevated gold levels.

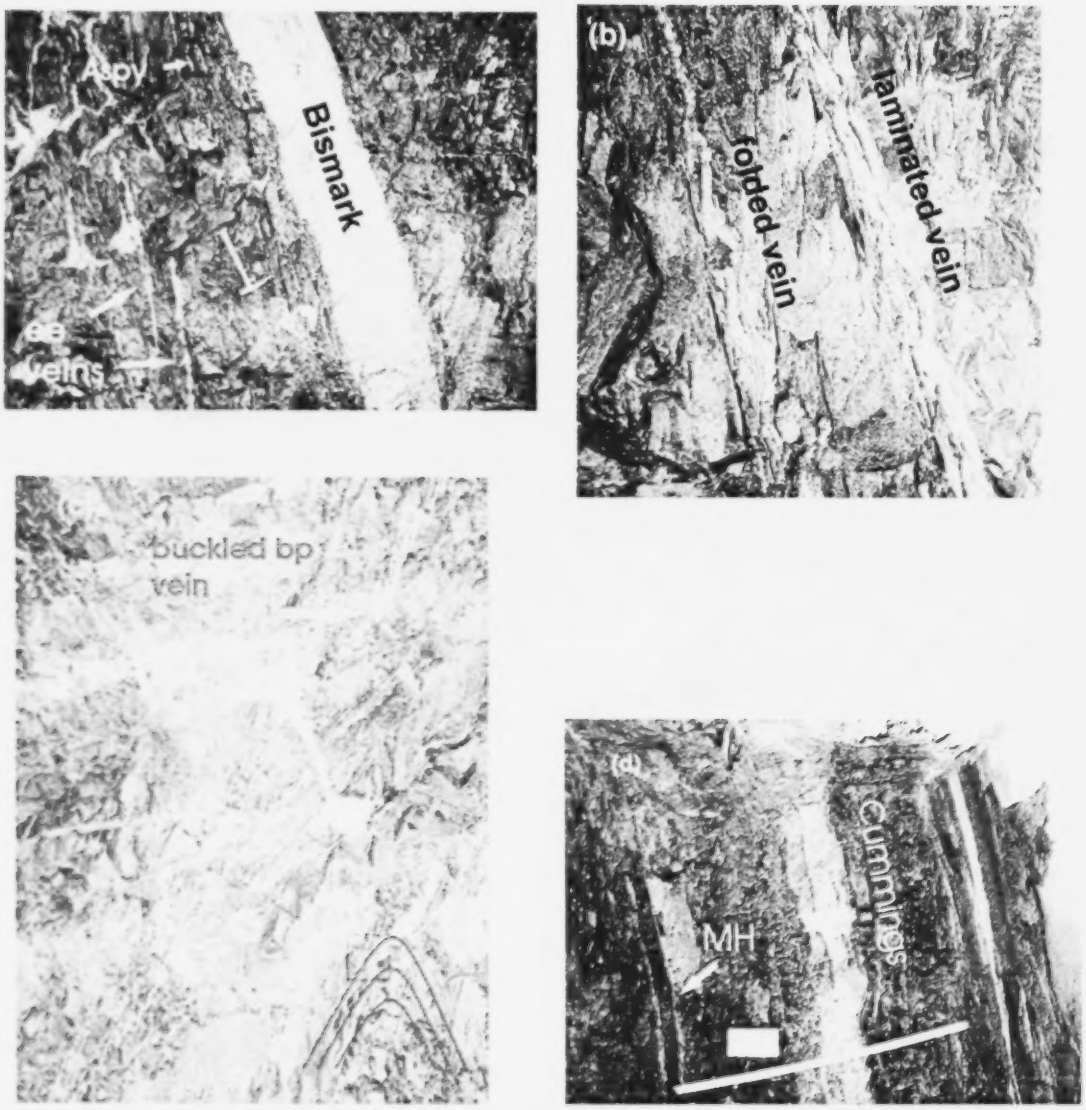
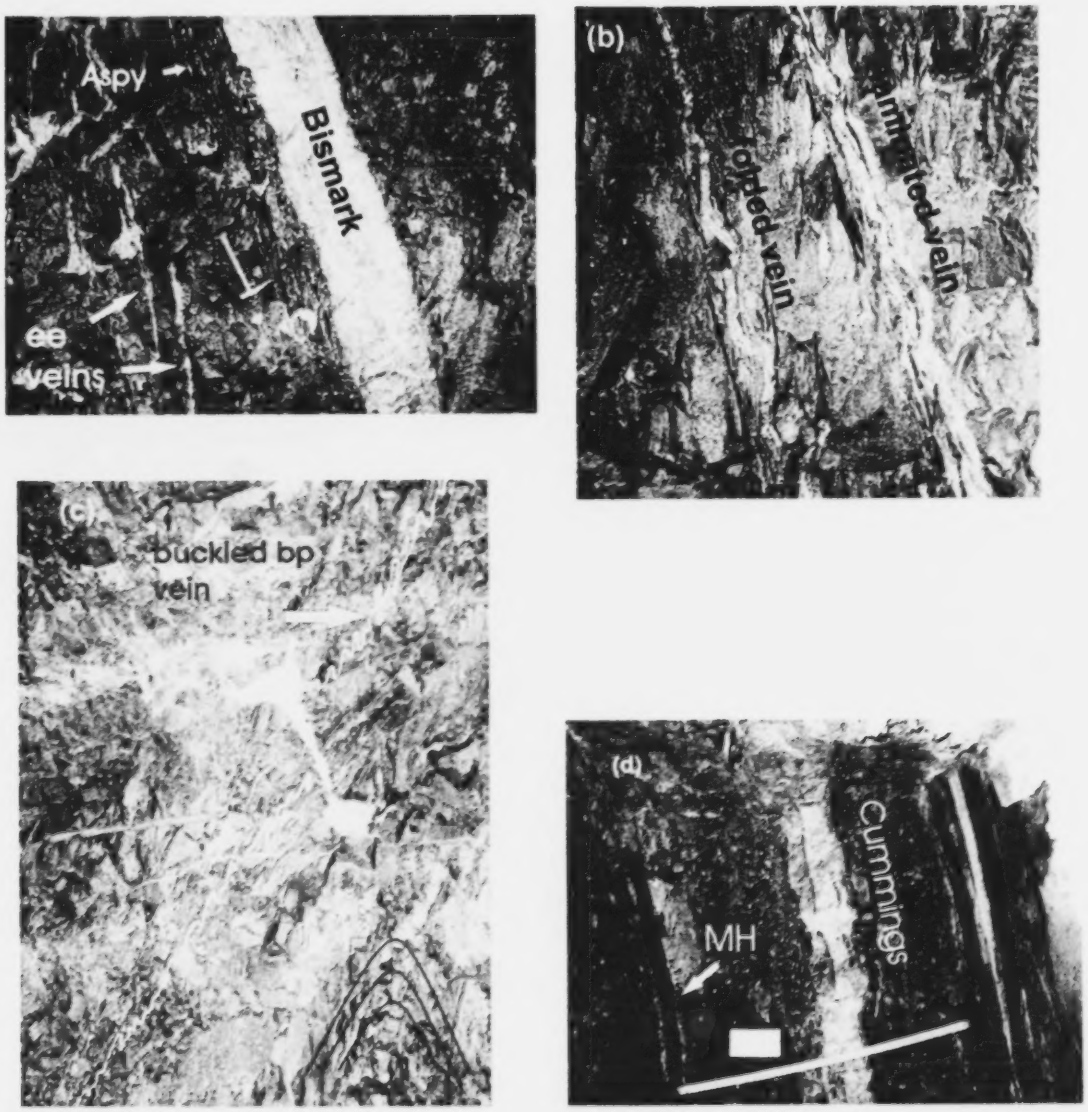


Figure 6. (a) Photograph of the Bismark vein in the decline. Note the coarse laminations, coarse arsenopyrite in the footwall slate, and en echelon (ee) veins. (b) Photograph of a laminated vein. (c) Photograph of tightly buckled vein exposed on the south limb near the fold hinge; relative position to fold shown in inset in lower right of photograph. (d) Photograph of east face of the Cummings Belt, east drift; MH = movement horizon.



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Buckled Bedding-parallel Veins

Three, variably buckled, bedding-parallel veins are found below the Bismark Belt. A thin (1-2 cm), tightly folded (locally isoclinal) bedding-parallel vein is exposed on the south limb in the remuck station, and in the fold hinge in the decline adjacent to the remuck station (Fig. 6c). Fold geometry is parasitic to the main anticline and fold tightness decreases down dip. The lack of buckled veins on steep fold limbs away from the hinge zone, both in the underground development and diamond-drill core, suggests that buckling is restricted to the hinge area.

Bismark Belt

The Bismark Belt is exposed in the hinge zone at surface, where it was previously mapped in the area between the highway and the portal (Kontak *et al.*, 1990). Underground, the Bismark Belt is exposed on the north limb in the sump and on the south limb in the remuck station and the main decline (inset, Fig. 2). The belt includes two bedding-concordant veins at surface, and in the remuck station and sump exposures of the decline. However, at lower levels in the decline only the upper vein is present and the vein generally thins down dip. The overall shape of the Bismark veins is consistent with a saddle reef (Fig. 3b). The veins occur within a black slate interval, with the upper vein in contact with a thick, overlying metasandstone-dominated interval (Irving Megacycle) (Fig. 3c). The veins consist of coarsely laminated and massive quartz with coarse-grained arsenopyrite. High concentrations of arsenopyrite occur in the footwall slate as medium to coarse crystals (Fig. 6a), locally forming bands parallel to bedding. Minor, fine-grained arsenopyrite occurs in the hanging wall metasandstone adjacent to the vein. Although these veins are impressive with respect to size and abundance of arsenopyrite, analytical results invariably indicate low contents of gold.

Irving Belt

Although historical surface work on the Irving Belt was extensive, only minor veins of a few centimetres width occur in the Irving Belt exposed in the decline, and only minor drifting was completed. The Irving Belt consists of two bedding-concordant veins in metasiltstone-dominated cycles near the top of the Irving Megacycle (Fig. 3c). On the west wall of the decline the upper vein occurs at the contact with overlying metasandstone with the other in the middle of the metasiltstone interval. En echelon and spur veins occur between these two bedding-parallel veins. The veins contain chlorite and pyrrhotite; however, arsenopyrite is rare.

Irving +1 Vein and ***Irving +2 Vein***

Two thin veins in metasiltstone at the top of the two sedimentary cycles overlying the Irving Belt are referred to as the Irving +1 and Irving +2 veins (Fig. 3c). These veins consist of thin (~1 cm) quartz veins with significant chlorite and minor pyrrohite. Although not significant in size or appearance, a sample of the Irving+1 vein yielded elevated gold levels.

Little North Belt

The Little North Belt (LNB) is an approximately 1 m thick interval of slate, which hosts three distinct bedding-concordant veins (Figs. 3e, 7): the *Little North footwall vein*, the *Little North twin vein* and the *Covey vein* (Fig. 7a). In addition, steeply dipping oblique veins, which are oriented at a small, clockwise angle (~ 10°) to bedding, and cross veins, which occur at a high angle to bedding, intersect the bedding-parallel veins of the Little North Belt. These veins often affect the thickness and character of the bedded veins (Fig. 7 a, c). Folded veins within a few metres of the hanging wall (e.g. Albert vein, Fig. 3e) and the footwall (Little North +1, +2, Fig. 3e) of the Little North Belt appear to be related to oblique veins of the Little North Belt and are discussed here. Bedding-parallel movement horizons consisting of millimetre-thick clay seams occur within the belt.

Little North footwall vein (LNf): The structurally lowest bedding-parallel vein, the Little North footwall vein (LNf), is typically a 2-4 cm thick and consists primarily of massive white quartz with a granular texture, and contains few to no inclusions or sulphide. Visible gold was not observed in this vein, except where crosscut by later oblique veins.

In the west drift, steeply dipping oblique veins in the hanging wall locally cut through the Little North Belt and merge with, and follow, the LNf vein. Where this occurs the LNf is effectively thickened, the vein has a laminated texture, and contains sulphide. In the east drift, this vein is connected with the Twin vein (below) by extensional spur veins of massive quartz (Fig. 7d) resulting in thickening of the LNf vein. Where this occurs significant coarse gold was observed.

Little North twin vein (LNt): The middle bedding-concordant vein of the Little North Belt typically consists of a pair of veins separated by a thin septa of wallrock, and is herein referred to as the Little North twin vein (LNt) (Fig. 7a). The upper margin of the upper vein invariably consists of approximately 1 cm of actinolite(?) with abundant pyrrhotite and arsenopyrite.

Covey vein (LNc): The uppermost vein, referred to as the Covey vein (LNc), is typically 6-15 cm in thickness and consists of variably laminated quartz. The vein is locally composite in character, including laminated margins with a core of massive quartz. The boundary between the laminated margins and the massive quartz is generally defined by a septa of wallrock. Locally numerous sites of visible gold were noted within the milky quartz segment along the septa of wallrock between the laminated and massive vein segments.

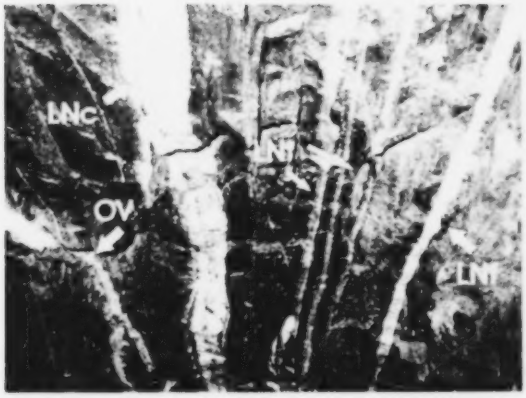
Oblique veins: Veins cutting stratigraphy at a low angle in both the hanging wall and footwall of the Little North Belt are referred to as oblique veins. The Albert vein (Fig. 7b) consists of a planar bedding-parallel vein occurring at the top contact of a sedimentary cycle on the east side of the decline and across the back of the decline. On the west face of the decline this vein crosscuts stratigraphy and includes folded and bedding-parallel segments, with the vein migrating down dip as it goes up section; the enveloping surface of the folds is shallower than bedding (Fig. 7b). At the floor of the decline on the west wall this vein is only about 1 m from the Little North Belt, which it likely intersects below the level of the decline. The geometry of this vein from the east to west walls of the decline reflects a moderate to steep plunge for the folds exposed on the west wall, as shown in Fig. 7b. Coarse visible gold was observed in the Albert vein on the east wall of the decline. Veins with similar geometry as the Albert vein are exposed in the hanging wall of the Little North Belt (Fig. 7). In the case of the Little North +2 vein, the continuity of the vein from west to east wall was observed in the floor of the decline as shown in Fig. 7b.

Several steeply dipping veins that intersect stratigraphy at a small angle are exposed in the hanging wall of the Little North Belt in the west drift (Fig. 7b). Their intersection with bedding, exposed on the hanging wall side (south) of the drift, plunges moderately to steeply to the east (Figs. 4c, 7b), similar to fold hinges of the folded segments of the Albert and Little North +2 veins. Some oblique veins are tightly folded where they cross the Little North Belt, with fold hinges plunging to the east, similar to the vein-bedding intersection. Where these oblique veins intersect bedding-parallel veins of the Little North Belt they merge with one of the veins, becoming bedding-parallel and effectively thickening the bedded veins (Fig. 7c). Within this drift the oblique veins dip steeper than bedding; however, these vein segments may represent the north limb of folded discordant segments (cf. Albert vein).

Although only limited structural data exist for the oblique veins, they show no apparent relationship to the shallow-plunging Mooseland Anticline, and the mechanism of vein development is not obvious. Viewed in a profile section of the

Figure 7. (next page) (a) Photograph of the back of the west drift on the Little North Belt showing the three principal bedding-parallel veins and oblique veins (width of photo 1.4 m). (b) Diagram of the west drift of the Little North Belt showing the geometry and relationships of veins. (c) Photograph of the back of the Little North Belt (west drift) showing an oblique vein merging with, and thickening, a bedding-parallel vein (height of photo 1 m). (d) Photograph of the east face of the Little North Belt (east drift) showing late quartz filling an extensional jog between the footwall and twin veins (with of photo 1.2 m). (e) Diagram showing the interpreted development of oblique veins formed as bedding-parallel and discordant (extensional) segments in response to bedding-parallel shear with folding of discordant segments durring progressive shear. (LNf = Little North footwall vein; LNt = Little North twin vein; LNc = Little North Covey vein; OV = Oblique veins.)

(a)



conjugate discordant veins

bedding-parallel vein

angular

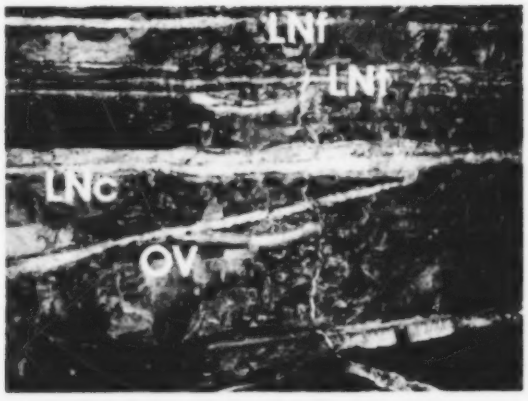
(e)

(b)

Oblique Vein

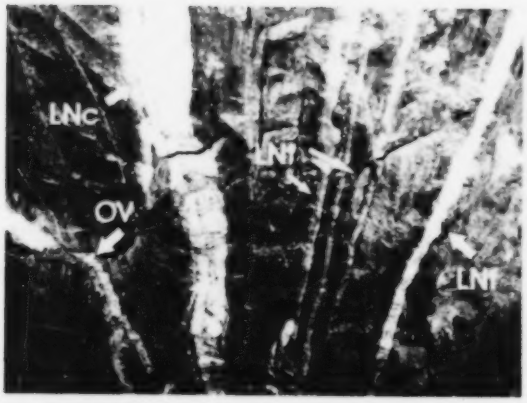
oikocryst

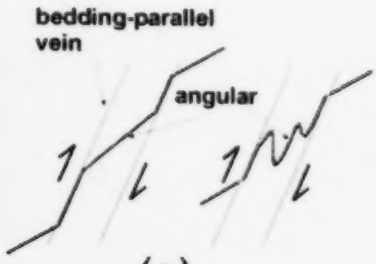
(c)



(d)

(a)

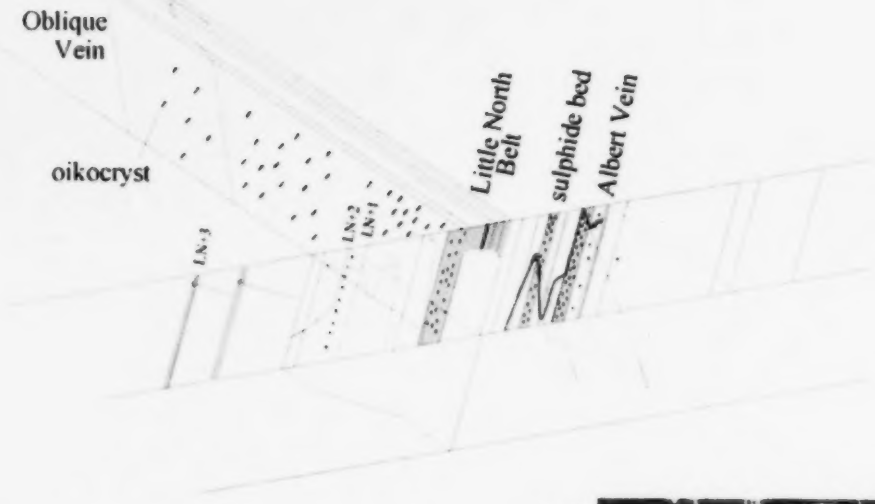




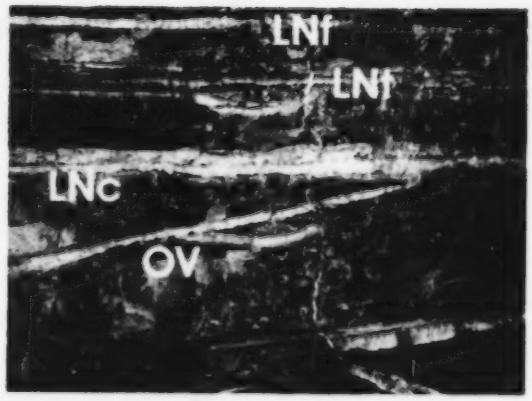
(e)

conjugate discordant veins

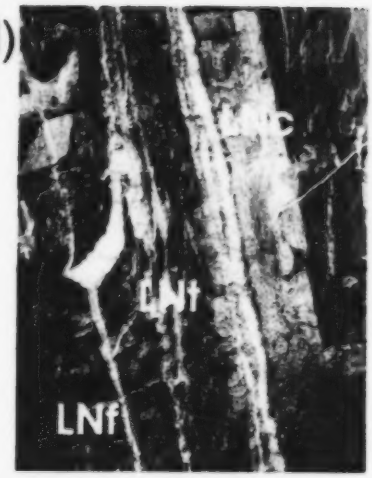
(b)



(c)



(d)



folds defined by the oblique veins, these veins show a similarity to "angular veins" (Faribault, 1899b; Armstrong, 1937) and can be explained by progressive bedding-parallel shear perpendicular to the fold hinges of the folded oblique veins (Fig. 7e). The oblique veins formed as linked bedding-parallel and discordant segments, the latter representing extensional veins, in response to oblique, sinsitral, reverse bedding-parallel shear, with discordant segments becoming folded (Fig. 7e). The kinematics of the oblique veins are not consistent with flexural-folding strain, which is recorded by bedding-concordant veins and oikocrysts, and the mechanism of vein formation is not understood. Although the shear strain implied by the folds is significant, as yet we have not recognized features recording this strain in the wallrock.

***Conjugate discordant veins*:** Steeply dipping discordant veins that strike approximately perpendicular to bedding form a systematic conjugate pair exposed along the walls and back of the drifts of the Little North Belt. One set dips steeply whereas the other dips moderately toward the west, such that the acute angle of the veins on bedding (or cleavage) is approximately bisected by oikocryst lineations, implying these veins record fold-related strain. These conjugate veins generally cut through other veins, indicating a relatively late origin.

Gold Mineralization: Although there is only limited exposure of the Little North Belt, coarse visible gold and elevated assays appear to be restricted to the areas where angular veins intersect and merge with bedding-parallel veins. Base metal sulphides, notably galena, sphalerite and chalcopyrite, are commonly found close to visible gold.

Cummings Belt

The Cummings Belt consists of an approximately 1.2 m thick interval dominated by metasiltstone, and is characterized by a single thick vein (Cummings vein) in the middle of the interval, and a thin vein that has not been mined near the top of the belt. Movement horizons occur near the footwall and hanging wall of the belt and define the walls of the drift.

***Movement Horizon*:** A significant movement horizon, defined by a 1-2 cm thick "clay" (fault gouge) layer, occurs near the footwall of the Cumming Belt and defines the footwall of the drift. This movement horizon is continuous over the approximately 45 m of strike length exposed and occurs at the top of a slate interval, which is part of the underlying metasandstone cycle, and the base of a thin (10 cm) strongly altered metasandstone bed within the Cummings Belt. A laminated vein locally occurs within the movement horizon, and is deformed (sheared) by the movement horizon. Coarse carbonate (calcite) locally occurs as matrix to a brecciated zone associated with the movement horizon. Displacement on the movement horizon is recorded by two offset discordant veins, which indicate 2.9 m of sinistral strike separation as measured in the back of the drift. Lineations recording the slip vector were not observed and, therefore, the displacement on the movement horizon was not determined. A less significant movement horizon characterized by a few millimetres thick clay layer occurs about 30 cm below the top of the belt, and defines the hanging wall of the drift.

***Cummings Vein (Ccv)*:** This vein occurs approximately 40 cm above the footwall movement horizon, roughly in the middle of the belt, and ranges from 15-50 cm in width. The vein consists predominantly of massive, milky white quartz, although a coarse laminated texture, similar to the Bismark Vein, is apparent. Spur veins occur in the footwall of the Cummings vein, where the contact with the wallrock is welded. The upper contact of the vein is characterized by a distinct band of chlorite and sulphide (arsenopyrite) within the vein and adjacent wallrock. Arsenopyrite is abundant as coarse crystals in the footwall wallrock, and as isolated coarse crystals in the hanging wall.

***Hanging Wall Vein (Chw)*:** A 2-4 cm thick quartz vein occurs within a 30 cm thick metasiltstone interval above the hanging wall movement horizon, and has not been mined.

Alteration

Several styles of alteration are associated with the vein system at Mooseland, including sulphide alteration (arsenopyrite, pyrrhotite, pyrite ± base metal sulphides), carbonate alteration and, most notably, widespread bleaching of the metasandstone. The oikocrysts described above are spatially restricted to the veined area and are also considered to reflect alteration associated with vein formation. The description of alteration given here is based only on hand sample observation, and we recognize the need for a petrographic study in order to fully establish the types and character of alteration.

Sulphide Alteration

Typical of all Meguma lode gold deposits, arsenopyrite occurs in wallrock adjacent to veins in the Mooseland deposit. The distribution of arsenopyrite in wallrock appears largely controlled by lithology, with typically high concentrations in slate adjacent to veins, and lower concentrations in metasandstone. A good example of this was observed in the Bismark Belt (Fig. 6a). Arsenopyrite also occurs in the wallrock of discordant veins.

Pyrrhotite locally occurs in anomalous concentrations in metasiltstone and slate. Although concentrations show a lithologic control, individual pyrrhotite aggregates define a down-dip lineation along cleavage, similar to the oikocrysts. Metasandstone-hosted pyrrhotite occurs as fine disseminations and as coarse aggregates up to several centimetres long, which locally appear to parallel cleavage. Small (few mm) pyrrhotite aggregates in metasandstone locally have a distinct rim of arsenopyrite. Although pyrrhotite is common throughout the Meguma Group stratigraphy, and may not be related to vein genesis, we note that pyrrhotite is common within the veins as well. Masses of pyrrhotite with arsenopyrite and chlorite locally occur adjacent to veins. Pyrite is common, but occurs mainly as films on fractures, in particular fractures cutting quartz veins.

Bleaching

Much of the metasandstone in the district exhibits a bleached colour variation, interpreted to result from intense hydrothermal alteration. Typically, the altered metasandstone consists of maroon and pale green areas producing a mottled texture, which commonly defines a fabric in profile sections that is locally parallel to bedding, but more commonly parallel to pressure-solution cleavage (Fig. 5a). In the latter case, dark (maroon) areas represent cleavage zones, presumably originally rich in phylosilicate minerals. The light coloured areas appear to be silicified, but the pale green colour reflects chloritization of biotite.

Discussion

Vein Array

The vein array at Mooseland, including bedding-parallel veins (some buckled), bedding-concordant en echelon arrays, saddle reefs, and discordant veins, is similar to vein arrays at other Meguma gold deposits (e.g. Horne and Jodrey, 2000; Horne and Culshaw, 2001; Sangster, 1980; Smith and Kontak, 1988). Horne and Jodrey (2002) and Horne and Culshaw (2001) demonstrated a syn-folding origin for these veins arrays, with veins recording flexural-shear strain. A similar origin is supported at the Mooseland deposit by the geometric relation of veins to the fold, and by limited kinematic data provided by en echelon veins. An exception is found in the oblique, folded veins found on the west side of the decline within and adjacent to the Little North Belt. The fold axis, fold geometry and the intersection of these veins with bedding implies these veins record oblique-sinistral, south-side-up reverse shear. Although the mechanism for this shear is not understood, we note the proximity of the Musquodoboit Batholith, which presumably exerted stress on the country rock during emplacement.

Controls on Mineralization

Variation in grade has been recognized within veins of Meguma lode gold deposits, and it is critical to understand potential controls on this variation for economic recovery. Faribault (1899b, 1913) referred to "ore shoots" and "pay zones", and described them as generally planar structural zones which commonly trend parallel to fold structure, such as the axial plane. Armstrong (1937) proposed his angular theory, where the intersection of "angular" veins with bedded veins defined ore shoot geometry. Recently, this theory was affirmed at the Forest Hills deposit, where ore shoots were defined by the intersection of angular and bedded veins, which plunge parallel to the fold hinge (Levesque and Campbell, 1990). At the Caribou deposit (Fig. 1) a discordant "flexure" with stockwork veins overprinting the bedded vein system defines a rich ore shoot (Bell, 1948) and steeply plunging ore shoots were defined at the Beaver Dam deposit (Smith and Kontak, 1988b).

Although it is early in the assessment of the Mooseland deposit, visual and analytical data suggest that zones of elevated gold (ore grade) in the Little North Belt are restricted to the areas where (relatively) late massive quartz veins overprint the pre-existing bedding-parallel veins. West of the decline, common occurrences of visible gold appear to be restricted to the area intersected by the "oblique veins" described above. These oblique veins are similar to "angular veins" described by Armstrong (1937), who noted that the intersection of angulars with bedding, and thus ore shoot geometry, varied from deposit to deposit, with no consistent relationship to the fold structure. If the occurrence of these veins defines the ore zone, then the associated "shoot" plunges steeply to the east, as defined by the intersection of these veins on bedding and fold hinges in the folded segments of these veins.

East of the decline, late quartz overprinting the bedding-parallel vein system is locally represented by quartz-filled dilational jogs linking the footwall and twin veins, with associated quartz variably thickening the bedding-parallel veins. Coarse gold was locally observed in the late massive quartz, both in the jog and bedding-parallel segments. The axis of the dilational jog is nearly horizontal, close to the hinge of the Moseland Anticline.

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Geology of the Southern Lobe of the Brazil Lake LCT-type Pegmatite (NTS 21A/04), Yarmouth County, Nova Scotia

D. J. Kontak

Introduction

Rare-element pegmatites are important resources for their economic concentrations of rare elements (e.g. Sn, Li, Ta, Rb, Cs, etc.), presence of high-quality industrial minerals (e.g. muscovite, spodumene, feldspar, mica), and occurrence of gem minerals (e.g. tourmaline, beryl). LCT-type pegmatites are rare-element pegmatites enriched in Li, Cs and Ta, and are often related petrogenetically to fertile, progenitor granites (see Černý, 1991a, for classification of pegmatites). Examples of LCT pegmatites that are currently mined include the Tanco pegmatite (Li, Ta, Cs, Be, Rb) of Manitoba, the Bikita (Li) and Kamativi (Li, Sn) pegmatites of Zimbabwe, the giant Greenbushes pegmatite (Sn, Ta, Nb, Li) of western Australia, and the spodumene pegmatites of North Carolina. Although spodumene-bearing pegmatites occur elsewhere in the Appalachians (e.g. Kings Mountain, North Carolina, and Peg Claims, Maine), the Brazil Lake pegmatite (BLP) is at present the only known occurrence in Nova Scotia.

The occurrence of spodumene and associated columbite-tantalite in the Brazil Lake area of southwestern Nova Scotia (Fig. 1a, b) has been known since 1960 (Taylor, 1967), but the occurrence has attracted only limited and sporadic work (see below) until recently. A more extensive program of drilling and stripping in 2002 by Champlain Resources Inc. exposed a large amount of pegmatite that was previously unknown. Work to date indicates that this pegmatite has the potential to produce high-quality feldspar, quartz, mica and spodumene with appreciable grades of tantalum (D. Black, personal communication, 2003). In order to assess this resource, develop a model for its petrogenesis, and assess the potential of the surrounding area, a detailed mapping program, with follow-up petrological studies, was initiated during the summer of 2003. This report presents the preliminary findings of this work. In addition, initial results of an integrated geochronological study are presented and, for the first time, an absolute age constraint on the time of emplacement of the pegmatite is provided. This age has important implications, not only for the petrogenesis of the Bazil Lake pegmatite, but also for exploration in this part of the Meguma Terrane.

Summary of Previous Work

Two separate lobes of pegmatite are currently exposed in the Brazil Lake pegmatite. These lobes are referred to informally as the northern and southern pegmatites, with reference to their location to the Holly Road (Fig. 2a). The Brazil Lake pegmatite was discovered in 1960 when a spodumene-bearing pegmatite boulder was found beside the Brazil Lake - Pleasant Valley Road (i.e. the Holly Road). Subsequent stripping of outcrops in the area revealed the presence of pegmatite north and south of the road. The first map of the area, indicating the distribution of pegmatite bodies, was produced by Taylor (1967), who also provided a modal analysis from an exposure of the southern outcrop (52% feldspar (K-feldspar and albite), 34% quartz, 11% spodumene, 3% muscovite, minor to trace beryl, apatite, and tourmaline). Metallurgical work done on a 272 kg sample of spodumene-rich (34.4% modally) pegmatite indicated 0.18-0.3 wt. % Fe_2O_3 in the spodumene. Shell Canada Ltd. evaluated the site with mapping, geophysics and geochemical sampling, and found variable, but elevated levels of Li (<275 ppm), Rb (<190 ppm), Cs (<100 ppm), Sn (<177 ppm) and Ta (<95 ppm) (Palma *et al.*, 1982). A mineralogical study was done on four representative samples from outcrops south of the Holly Road by Hutchinson (1982), collected as part of the Shell Canada Ltd. exploration program. Significantly, Hutchinson

Kontak, D. J. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 41-68.

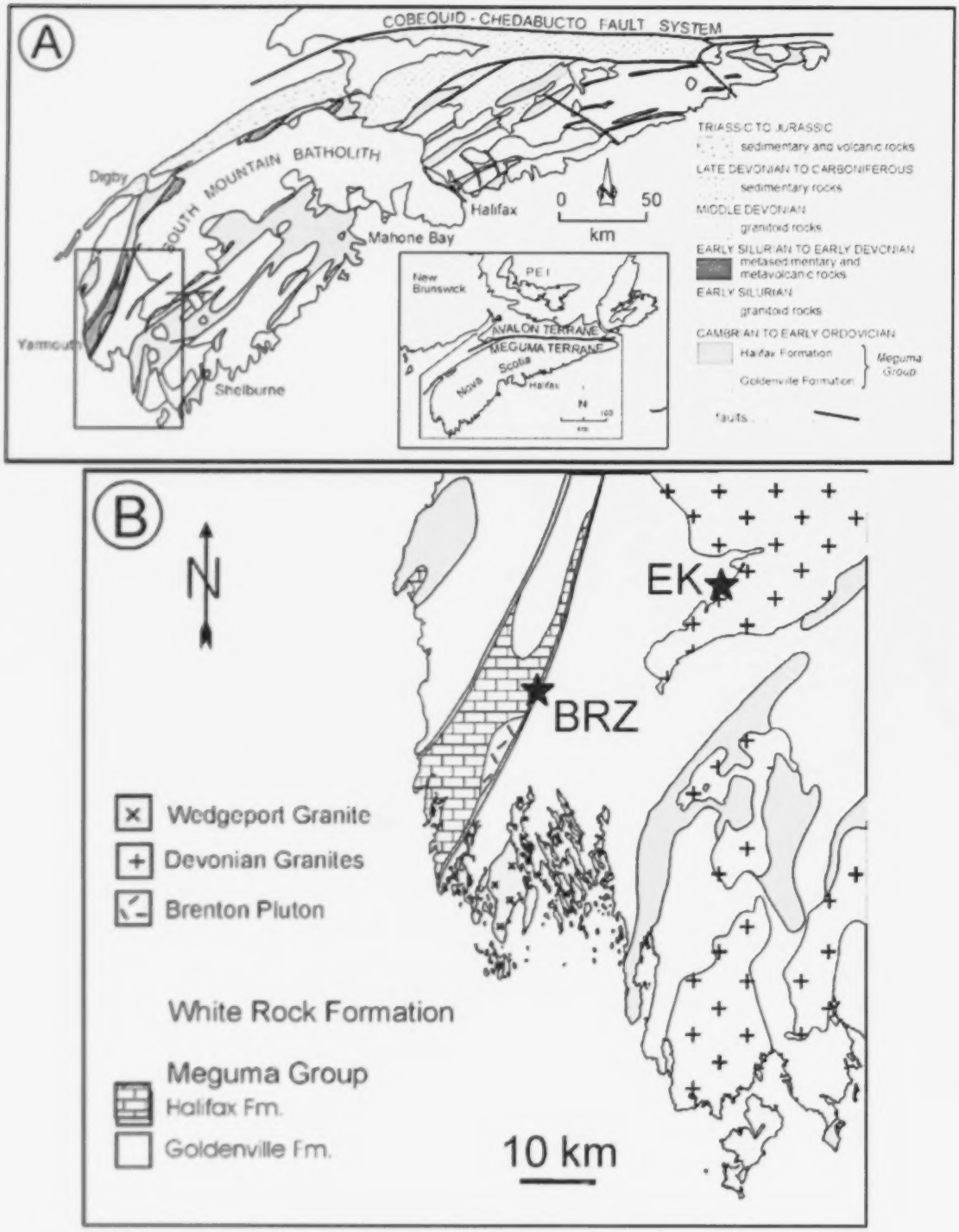
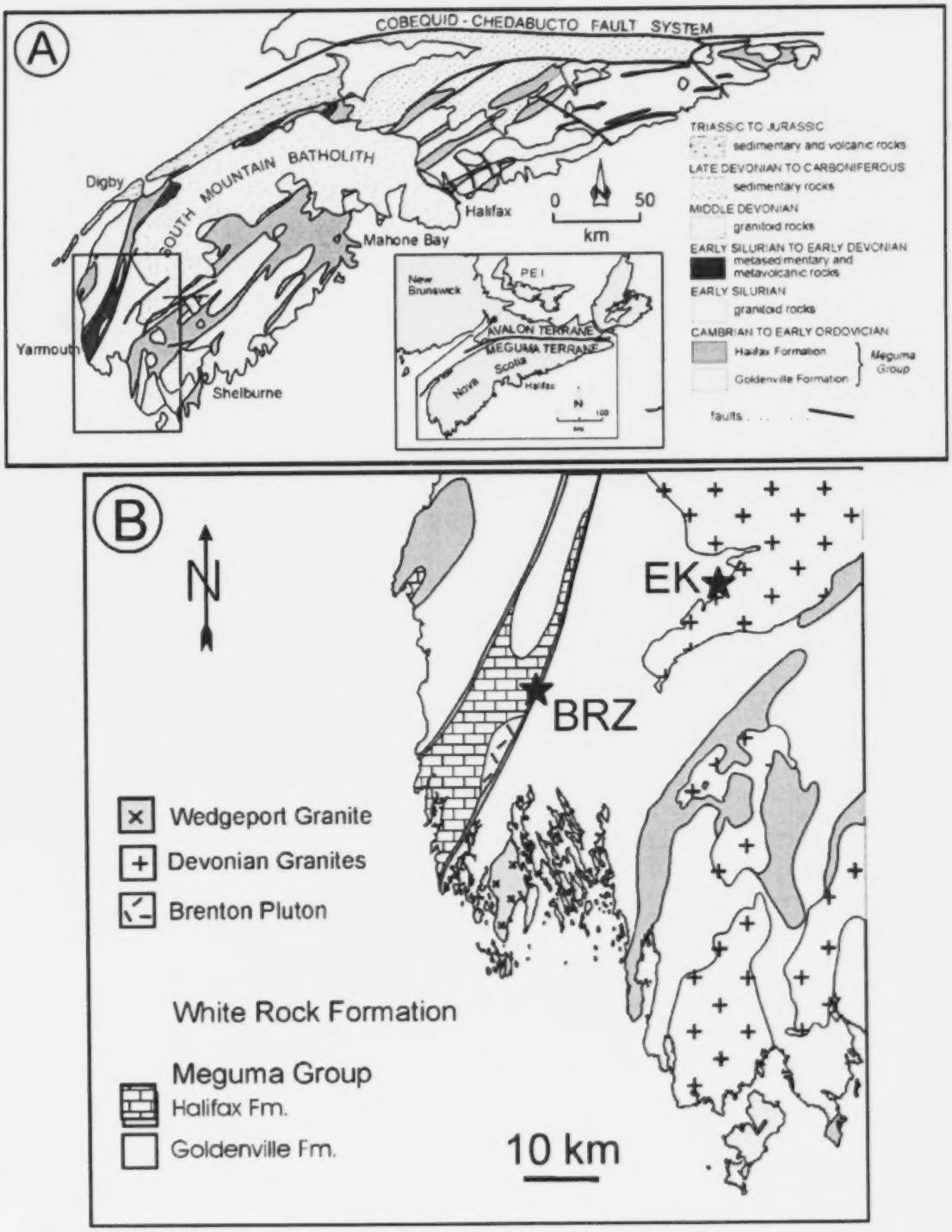


Figure 1. (A) Regional geological map of southern Nova Scotia showing the location of the study area (Fig. 1B inset). (B) Geological map of southwest Nova Scotia (after White *et al.*, 2001) showing location of Brazil Lake pegmatite (BRZ) and the East Kemptville tin deposit (EK).



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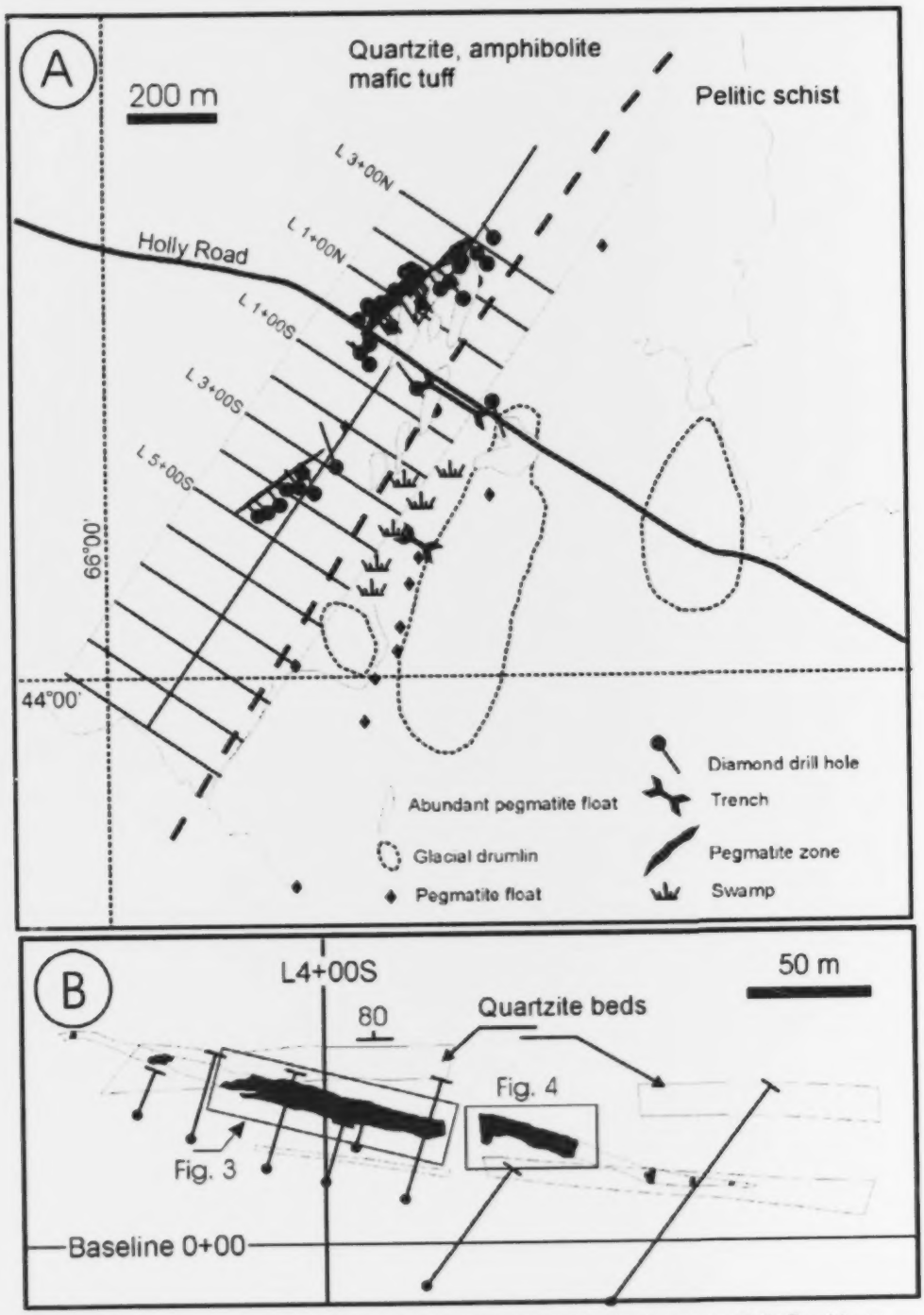


Figure 2. (A) Geological setting of the Brazil Lake pegmatites with reference to the Holly Road (map modified after map of D. Black, Champlain Resources Inc., 2003). The pegmatites located north and south of the Holly Road are referred to informally as the northern and southern pegmatites, respectively. (B) Geological setting of the southern pegmatite, Brazil Lake.

(1982) recognized a metasomatic halo about the Brazil Lake pegmitite, revealed by the conspicuous presence of tourmaline in the quartzite and the rare occurrence of the Li-bearing amphibole homquistite, generally diagnostic of nearby Li-bearing pegmatite (e.g. London, 1986a).

MacDonald *et al.* (1992) conducted a geochemical study over the pegmatite area in order to evaluate the signature of this deposit within the surficial environment, including the vegetation. Corey (1993) drilled the northern pegmatite as part of a larger program undertaken by the Nova Scotia Department of Natural Resources, and concluded that it was a single, zoned, sub-vertical dyke of 10-25 m thickness. Sampling and analysis of this core by Gwalia Resources of Australia in 2002 provided the first extensive geochemical data set (see below). Hughes (1995) provided a more comprehensive petrological investigation of the northern pegmatite that included mineral chemical data, recognition of new minerals, the first fluid inclusion observations and data, and a modern petrogenetic model.

Geological Setting

The study area is located in the southwestern end of the province, just past the western extent of the 380 Ma, peraluminous South Mountain Batholith (SMB), and roughly 25 km from the past-producing (1985-1992) East Kemptville tin deposit (Fig. 1b). The Brazil Lake area is underlain by a mixed package of metasedimentary and metavolcanic rocks, which are cut by small pegmatite bodies, and the Brenton Pluton, which is also transected by pegmatites. The oldest rocks are part of the Cambro-Ordovician Meguma Group, which consists of an older, sandstone-dominant Goldenville Formation, and younger, overlying siltstone and shale-dominant rocks of the Halifax Formation. Overlying the Meguma Group are mixed sedimentary and volcanic rocks of the Silurian White Rock Formation. The sedimentary stratigraphy is dominated by massive quartzite with minor pelitic beds. The volcanic rocks are of basaltic composition, although west of the study area near Yarmouth felsic rocks also occur (White *et al.*, 2001). A recent U/Pb zircon age of 438 Ma was obtained for the volcanic rocks (MacDonald *et al.*, 2002). The Breton pluton, a probable subvolcanic intrusion related to the White Rock Formation based on its chemistry (MacDonald *et al.*, 2002) and 439 Ma U/Pb zircon age (Keppie and Krough, 2000), is in fault contact with both the White Rock and Halifax formations. The intrusion is highly deformed and corresponds compositionally to a biotite-muscovite syenogranite to monzogranite. Within the intrusion are two mica-bearing, garnet-tourmaline pegmatites that commonly cut the fabric of the granite.

Deformation in the area occurred during the Acadian Orogeny and produced northeast-trending, upright folds with a shallow southwest plunge and a related penetrative fabric. An overprinting, probably Alleghanian age fabric (Culshaw and Reynolds, 1997), crenulates the S1 fabric and the fold axis is gently south-southeast plunging (White *et al.*, 2001). The metamorphic facies varies from greenschist to amphibolite, with higher facies localized to the contact area between the White Rock and Goldenville formations on the south side of the Yarmouth Syncline (MacDonald, 2000). This also coincides with a boundary between two distinct trends of vertical gradient magnetics, which O'Reilly *et al.* (1992) termed the Deerfield Shear Zone.

In the area of the BLP, the host rocks are a northeast-trending sequence of folded meta-volcanics and metasediments of the White Rock Formation that fall in the middle of the Yarmouth Syncline (Fig. 1b). Rock types include fine- to coarse-grained amphibolite, minor mafic tuff, dark green-black pelite, psammite and a fine-grained, tourmaline-bearing, silica-rich rock adjacent to the pegmatite. The pelitic unit typically contains staurolite, garnet and andalusite, whereas tourmaline occurs in the amphibolite adjacent to the pegmatite (thin section observation). In addition, elliptical, buff-colored plagioclase clots, with steep lineations, occur in amphibolite near the pegmatite. The silica-rich nature of the quartzite may be primary or, in part, an exomorphic alteration (i.e. silicification) related to pegmatite emplacement (D. Black, personal communication, 2003).

Geology of the Brazil Lake Pegmatite

The Brazil Lake pegmatite consists of two distinct sheets that occur south and north of the Holly Road (Fig. 2a), referred to informally as the northern and southern pegmatites. Previously, the few scattered outcrops of these pegmatites that represent their surface expression were mapped by Hutchinson (1982) and Hughes (1996), respectively. Essentially, both these workers recognized three zones within the BLP that were characterized by modal enrichment in spodumene, K-feldspar (KF) and albite (their aplitic albite). The southern pegmatite is dominated by zones of megacrystic blocky K-feldspar (BKF), spodumene (Spd), fine-grained albite, and coarse-grained pegmatite composed of variable proportions of Spd-KF-quartz. Further subdivisions can be made based on textures, grain size and mineral proportions. Subdivision of the BLP compared in general with that observed in albite-spodumene rare-element pegmatites, which are otherwise generally characterized by a heterogeneous and complex internal structure (Černý, 1991a).

The pegmatites are steeply-dipping sheets (i.e. 75-80° SE) of 10-20 m width that strike north-easterly at ca. 30-40°. Although the pegmatites lie within the White Rock Formation, they obliquely crosscut bedding, such that they are in direct contact with quartzite, pelitic schist and amphibolite along their strike length. In the quartzite unit marginal to the pegmatite, tourmaline occurs disseminated as isolated grains or aggregates, often with radial habit and rarely exceeding 3-5%. The overall dimensions of this zone remain to be defined as part of future work. There is no regional structure that the BLP appears to have accessed during emplacement, and contacts between pegmatite and wallrock are welded with no apparent structural discontinuity or locus of subsequent displacement. On strike and southwest of the southern pegmatite is a recently exposed quarry that does not contain pegmatite; thus, the southern pegmatite body either plunges to the southwest beneath these exposures, pinches out, or is faulted off.

Geology of the Southern Pegmatite

Stripping of the southern pegmatite in 2002 provided complete exposure of this unit and it was mapped in detail in 2003 (Figs. 3, 4). Below is a summary of findings resulting from this mapping. The northern pegmatite is scheduled to be stripped in 2004 and will be subsequently mapped in detail.

Wallrocks

The immediate wallrock consists of an interbedded sequence of mafic volcanics (amphibolites), pelitic schist, and quartzite. There is no apparent structural continuity between the pegmatite and wallrocks, the contact is a zone of faulting or shearing. The sequence strikes northeastwards and dips steeply to the northwest. Adjacent to the pegmatite, all three rock types are found due to the fact that the pegmatite is oblique to the strike of the beds. Within the amphibolitic rocks occur thin, beige ellipses, ca. 0.5-1 cm long, of plagioclase aggregates that are oriented subvertical in the cleavage plane. Along the margin of the pegmatite occur tourmaline-rich (i.e. 40-50%) xenoliths of altered amphibolite; tourmaline grains are <1-2 cm long. In thin section tourmaline locally comprises 10-20% of the mode of amphibolite adjacent to the pegmatite. The quartzite beds locally lose their buff colour adjacent to the pegmatite, as noted above, which may relate to silicification. Chemical analysis of these rocks indicates up to 98.5% SiO_2 (D. Black, personal communication, 2003). No megascopic change is noted in pelitic beds adjacent to the pegmatite.

Zoning in the Southern Pegmatite

There is a distinct development of zones within the southern pegmatite that permits mapping out areas that are characterized by a dominant mineral or texture, and these are discussed below. It should be emphasized that some variability may occur in such zones, but in general one zone can be easily distinguished from a contrasting zone. These zones (Figs. 3, 4) are dominated by blocky K-feldspar or their albitized equivalents, spodumene-rich areas,

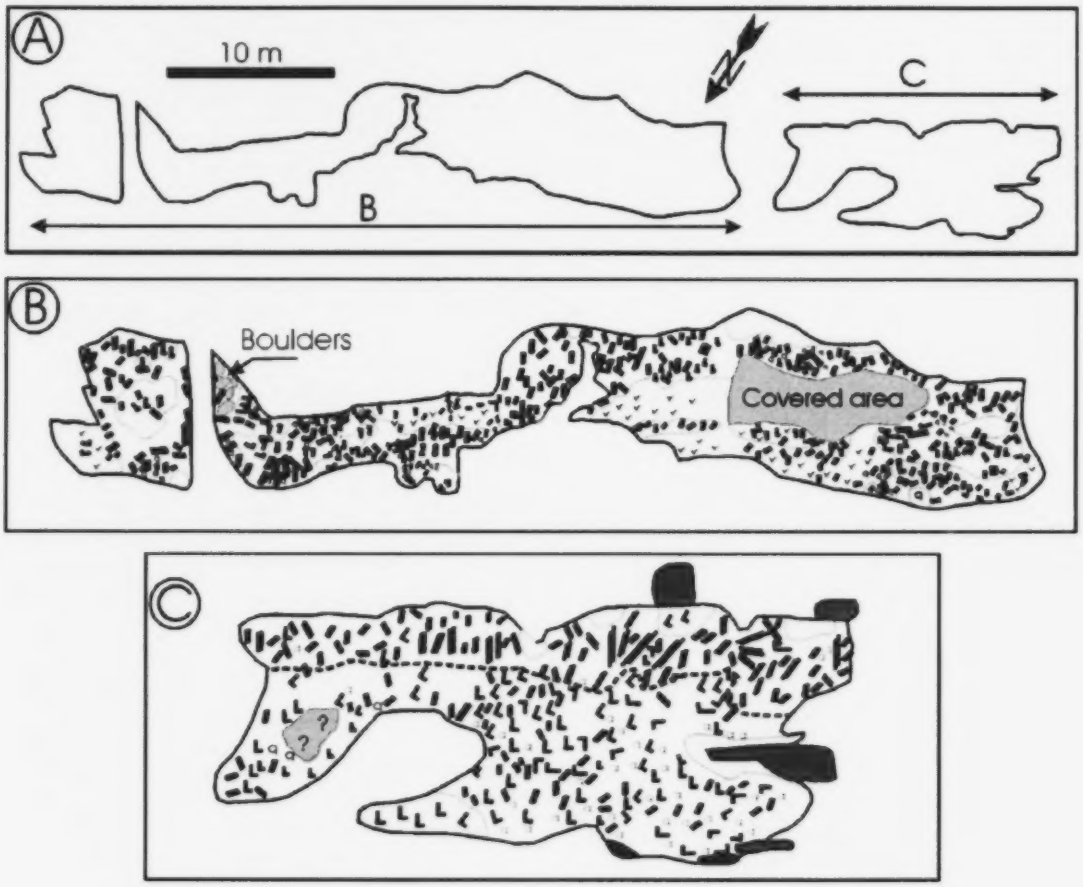


Figure 3. Detailed geological maps of outcrops comprising the southern pegmatite (see Fig. 2 for location). Figure 3A shows the location of the outcrops and in Figures 3B and C are the detailed geological features of these pegmatitic outcrops.

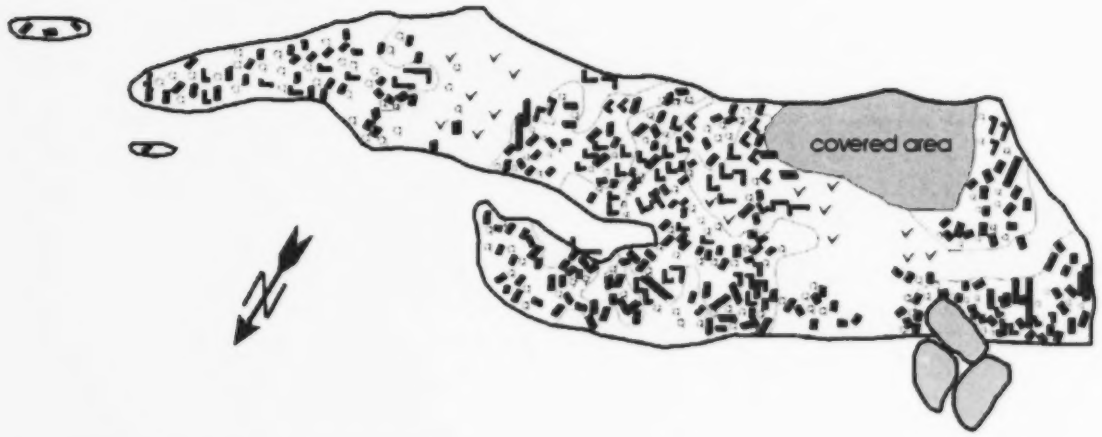


Figure 4. Detailed geological map of part of the southern pegmatite. See Figure 2B for location of the outcrop and Figure 3 for the legend.

coarse matrix pegmatite, and a beaded quartz-textured zone.

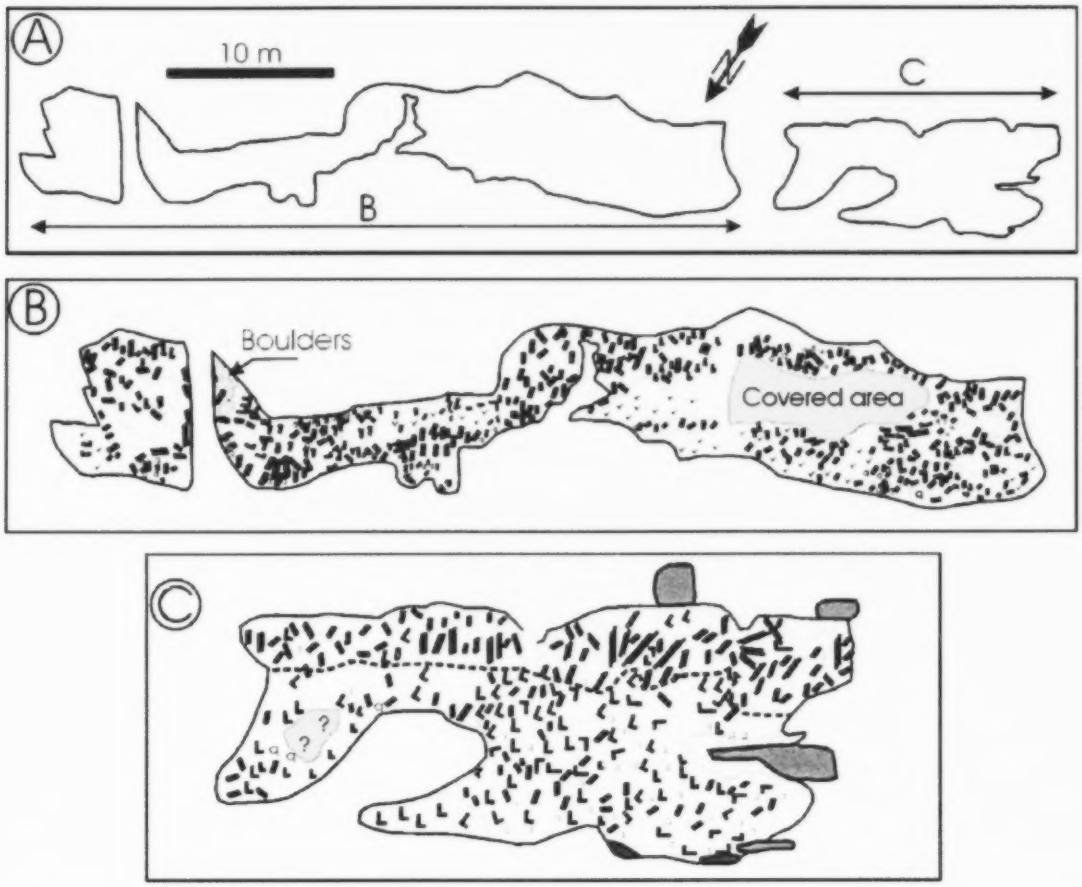
Marginal or Contact Zone

There is no well-developed, continuous wall zone to the southern pegmatite. Wall zones consisting of fine-grained granite or aplite are common in other zoned rare-element pegmatites (e.g. Černý, 1991a; Simmons *et al.*, 2003). However, locally within 1 m of the contact there is a marked decrease in the grain size and euhedral spodumene oriented perpendicular to the contact is surrounded by smaller quartz euhedra within an aplite matrix (Fig. 5). The mineralogy of this matrix is presently undetermined. Elsewhere the contact zone may become more siliceous, as seen along the southwestern contact where both the abundance and grain size of quartz increases (Figs. 3c, 8g). Although there may be alignment of quartz and spodumene subparallel to the contact (Fig. 4), this contrasts markedly with the general orientation of megacrystic K-feldspar and spodumene perpendicular to the contact elsewhere (Figs. 3b, c, 6c, e).

Blocky K-feldspar (BKF) Zones

Zones of BKF, with individual crystals of <1.5 m (Figs. 6a, c, e), occur throughout the pegmatite (Figs. 3b, c), but in the northeastern end such zones are rarely preserved and, instead, have been albitized (Fig. 6b). These large megacrysts are subhedral to euhedral (compare Figs. 6a to e) and are generally inclusion free on a macroscopic scale. Although zones may be dominated by K-feldspar, they may also contain variable amounts of quartz and spodumene (e.g. Figs. 6a, e). The BKF crystals vary from equant to elongate and, in the latter case, the long axis is oriented perpendicular to the contact (Fig. 6c). Where the K-feldspar has an elliptical shape (e.g. Fig. 6b), the outline may reflect post-crystallization modification due to superimposed stress, which is not uncommon in pegmatites (Černý, 1991a). The BKF zone varies from greyish, representing the freshest material, to various hues of pinkish-red, and white where altered to fine-grained albite. On fresh surfaces the K-feldspar contains a flame perthite texture.

Intergrown with the BKF zones may be coarse (<10-15 cm) quartz of anhedral elliptical shape to euhedral grains (Figs. 6a, 8c). Where this type of quartz coalesces and becomes continuous, the term beaded quartz texture (BQT) is used to describe the feature and it can be mapped within the pegmatite (Figs. 3, 4, 6b, d). Thus, there is a continuum between BKF and BQT zones. In addition, there is a continuum between BQT zones dominated by quartz, and more polymineralic (i.e. quartz± muscovite±spodumene±feldspar) areas where the proportions of minerals vary. In these areas the



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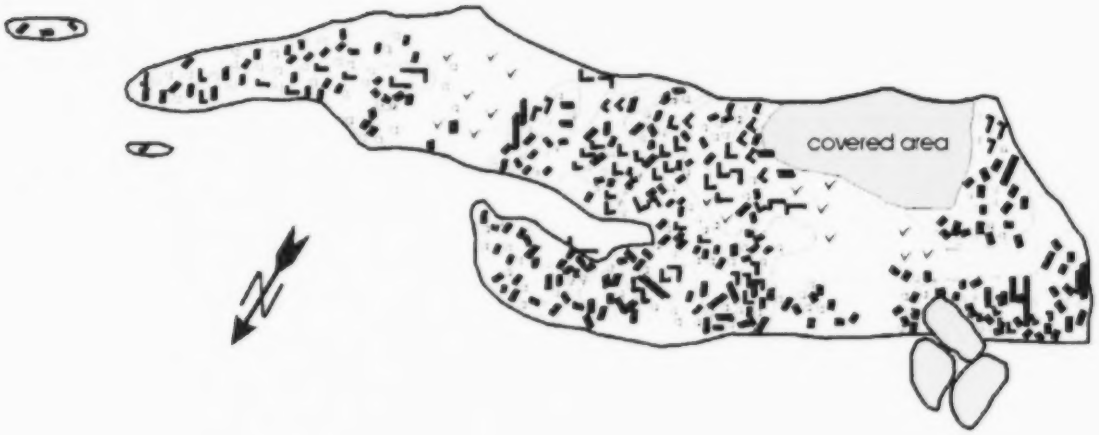

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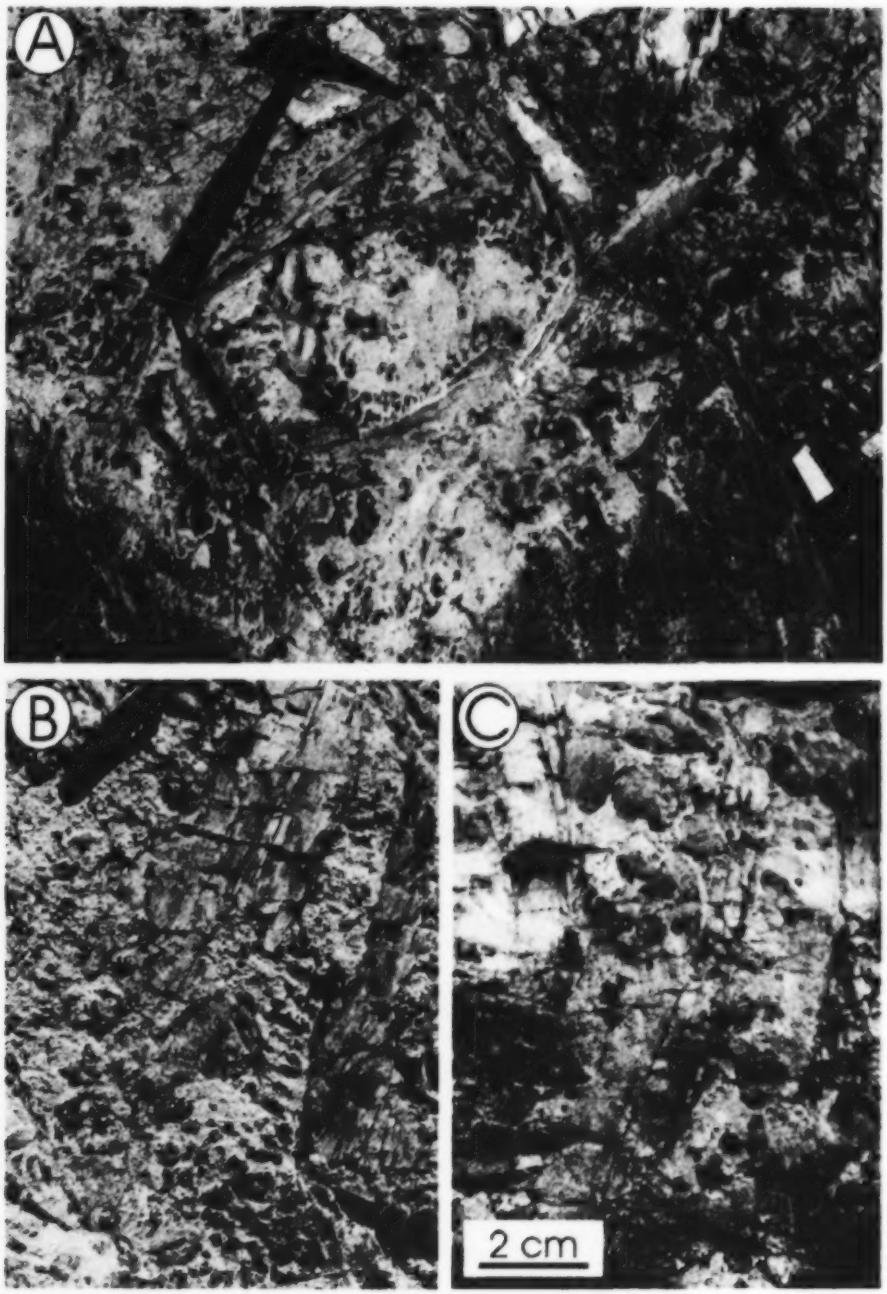


Figure 5. Outcrop photos of border zone, southern pegmatite, Brazil Lake. (A) Spodumene megacrysts in upper right bordered by smaller spodumene crystals in matrix of fine-grained, sacchroidal-textured aplite/albite with quartz grains. Note that the long dimension of the spodumene crystals are oriented perpendicular to the contact (lower left). (B) Enlargement of part of Figure 5A showing intergranular material between spodumene megacrysts. Note the quartz grains that are growing with their c-axis perpendicular to the spodumene crystals. (C) Close up of wall zone texture showing the euhedral, translucent quartz grains in the fine-grained aplitic material.

BKF is often replaced by either fine-grained sacchroidal albite or cleavelandite (Figs. 6b, f, g). Cut slabs of this K-feldspar indicate that the albitization process is controlled by fractures (Fig. 6a inset) that gradually coalesce to form massive albite, and further alteration may result in the fine-grained albite becoming cleavelandite (Fig. 6f).

Spodumene Zones

Spodumene-rich zones are dominated by megacrystic spodumene that reaches is maximum size (i.e. <1.5-2 m) in the central part of the pegmatite and diminishes in grain size toward the margin (<0.5 m) (Figs. 7a, b, f). One particularly spodumene-rich zone is observed along the southeastern part of one of the exposed outcrops where the spodumene defines a distinct fabric (Fig. 3c). Where the megacrysts of spodumene are preferentially oriented, their long axis generally lies perpendicular to the contact zone (Figs. 3, 4, 7b, f), although internally more random orientations occur. Spodumene is often intergrown with BKF as subparallel grains oriented perpendicular to the contact (Fig. 6a) and penetrating grains (Figs. 6e, 7c, d). The megacrysts of spodumene are euhedral and inclusion free, except for subhedral to euhedral quartz along their margins. The pods of spodumene consist of several interlocking grains of different size with minor amounts of intergranular quartz (euhedral to anhedral), feldspar (K-feldspar or albite), finer-grained spodumene, and muscovite (Fig. 7f). In some cases, quartz grains are oriented perpendicular to spodumene, as if the grains had acted as a site of nucleation for quartz (Fig. 5c). The spodumene is rarely deformed, but rare cases of kinking have been observed.

Albite Zones

Large areas (many square metres) of pegmatite contain fine-grained albite after primary BKF (see above and Fig. 6b). The occurrence of residual K-feldspar as irregular-shaped, multi-centimetre crystals is the evidence for this replacement (Fig. 6g), along with the presence of albite lining fractures that transect BKF where the albitization process was arrested (inset Fig. 6a). These albite zones are massive, have a sacchroidal texture, and may contain disseminated apatite and shiny dark phases that include tantalite and dark brown cassiterite. As already noted above, the zones are generally subdivided into several ellipitical subzones by the BQT material. Internally these albite zones may develop into coarser albite (cleavelandite) and also have a vuggy texture with 1-2 cm pockets lined with clear euhedra of albite and quartz. In one exceptional case where this was observed, a zone of coarse, primary BKF is overgrown by a layer of comb quartz and radial albite (?), which is succeeded by a zone of fine-grained albite and then a distinct vuggy zone dominated by secondary fine-grained albite and cleavelandite.

The vuggy albite-rich zone is dominated by fine-grained albite, but locally a variety of quartz types occur along with concentrations of coarse, clear to light brownish and silvery mica. The quartz occurs in the following manner: (1) elliptical to rounded, anhedral aggregates (?) of clear to dark grey quartz in a sea of albite, and (2) as millimetre to centimetre euhedra within multi-centimetre size vugs.

In thin section the albite zone is >98% albite with minor residual K-feldspar and accessory amblygonite, white mica, Ta-Nb oxides, garnet, triplite, cassiterite and zeolite (identified to date). The albite is subhedral to euhedral, is free of mineral inclusions, albite twinned and exceptionally fresh. Albite crystals are preferentially aligned, but not strained. Thus, thermal annealing of the albite outlasted any stress that may have been responsible for the orientation of albite. Accessory phases are subhedral to euhedral and are preferentially concentrated in zones, perhaps reflecting fracture-controlled fluid migration. Zeolite occurs as the latest stage accessory mineral and occurs alone along fractures. The texture of the K-feldspar is described in detail below.

Intergranular Zones

The areas between megacrystic spodumene and BKF, including albitized zones, consist of coarse-grained (<20-30 cm), intergrown quartz, spodumene, feldspar (K-feldspar or albite) and muscovite, in varying proportions (e.g. Fig. 8a). For purposes of this general description, the material is referred to as coarse leucogranite (lcgr) and may include the beaded quartz texture material (Fig. 6b) described previously. Textures in the

leucogranite zones are variable, and include: (1) delicate intergrowths of quartz and cleavelandite (secondary albite; Fig. 8b), (2) anhedral to euhedral quartz in fine-grained albite (after K-feldspar, Fig. 8e, f), (3) coarse cleavelandite-spodumene, (4) coarse books of muscovite intergrown with quartz ±feldspar± spodumene, and (5) coarse euhedral intergrowth of quartz-feldspar between metre-size spodumene (Fig. 7g).

This leucrogranite material also includes large areas that are not dominated by BKF or spodumene megacrysts and, instead, consists of coarse leucogranite and is referred to as matrix in Figures 3 and 4. Such material is best seen along the western side of the outcrop shown in Figure 3c, where there is a distinct enrichment in quartz, in places including intergrowth of quartz and euhedral K-feldspar. Such an area may be a candidate for the best estimate of the primary bulk composition of the pegmatitic melt.

White Mica Zone

There are no zones of significant size that are dominated by white mica, such that they can be mapped out. Instead, mica occurs as pods replacing parts of BKF, disseminated within albitized zones, and intergrown with coarse leucogranite zones as both primary and secondary phases. Thus, although there is some primary mica as part of the leucogranite intergranular zones, the majority of the mica is secondary in origin.

Wallrock Inclusions

Xenoliths of wallrock amphibolite occur as small to medium size (<1 m) inclusions within the marginal parts of the pegmatite. The xenoliths may contain abundant, black to dark brownish, coarse-grained (<2-3 cm) tourmaline. In thin section they are uniformly dark brown to slightly zoned.

Mineralogy and Mineral Chemistry of the Southern Pegmatite

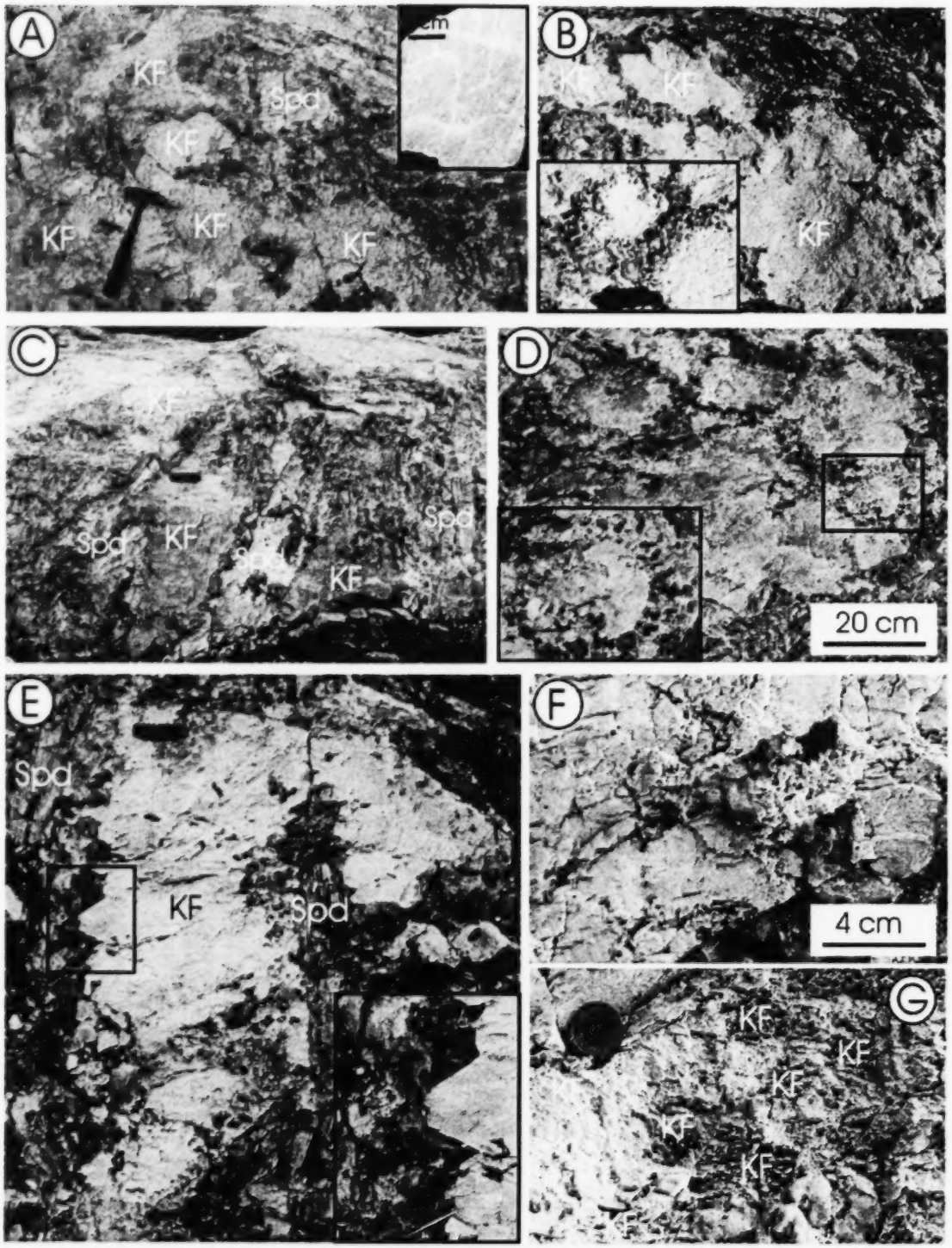
A detailed evaluation of the mineralogy and mineral chemistry of the pegmatite is currently in progress. A preliminary assessment is presented below. Major and minor element analyses were determined using wet chemical methods (DalTech, Halifax) and electron microprobe analysis (EMPA; Dalhousie University Earth Science Department), whereas trace elements were determined by ICP-MS (Memorial University, Newfoundland). Imaging of mineral phases and qualitative analyses of some minerals were also done using the electron microprobe with an energy dispersive operating system. The mineralogy can be subdivided into primary and secondary stages; the first represents formation during the magmatic stage, whereas the latter is of hydrothermal origin. There is a continuum in formation of some minerals (e.g. apatite) such that it is difficult to distinguish primary and secondary origins. As is the case for other minerals (e.g. K-feldspar) their texture and chemistry is a mixture of primary and secondary stages.

Major Mineral Phases

K-feldspar

This was the most dominant mineral phase in the

Figure 6. (next page) Outcrop photos showing features of K-feldspar (KF), along with some spodumene (Spd) in southern pegmatite, Brazil Lake. Knife for scale is ca. 10 cm long. (A) Megacrysts of fresh KF in blocky KF zone; note the subhedral to euhedral outlines of the megacrysts. Dark material between the KF are quartz-rich areas, in part with beaded quartz texture (BQT). Inset photo is cut slab of a partially altered KF showing albite invading along fractures. (B) Blocky KF zone with intergranular quartz with the BQT. Note that the white color of the KF is due to partial to complete replacement by fine-grained albite. Inset photo shows close up of the BQT, which consists of euhedral quartz, muscovite books, and minor Spd here. (C) Oriented KF and Spd megacrysts near contact of the pegmatite (lower part of photo). (D) Blocky KF zone with megacrysts of KF. Inset photo shows a mushroom-shaped KF with zonally arranged quartz grains around it. Note the BQT in the background. (E) Large KF megacryst intergrown with Spd and oriented perpendicular to pegmatite contact. Note that the KF is in contact with translucent quartz on left side with euhedral faces (see inset). The KF is whitish here because of alteration to albite that includes both fine-grained sacchroidal albite and euhedral cleavelandite. (F) Close up of previous area in Figure 6E showing albitized KF, secondary cleavelandite, and porous texture of the feldspar that was generated during alteration. (G) Close up of albitized KF megacryst with residual patches of KF (marked KF).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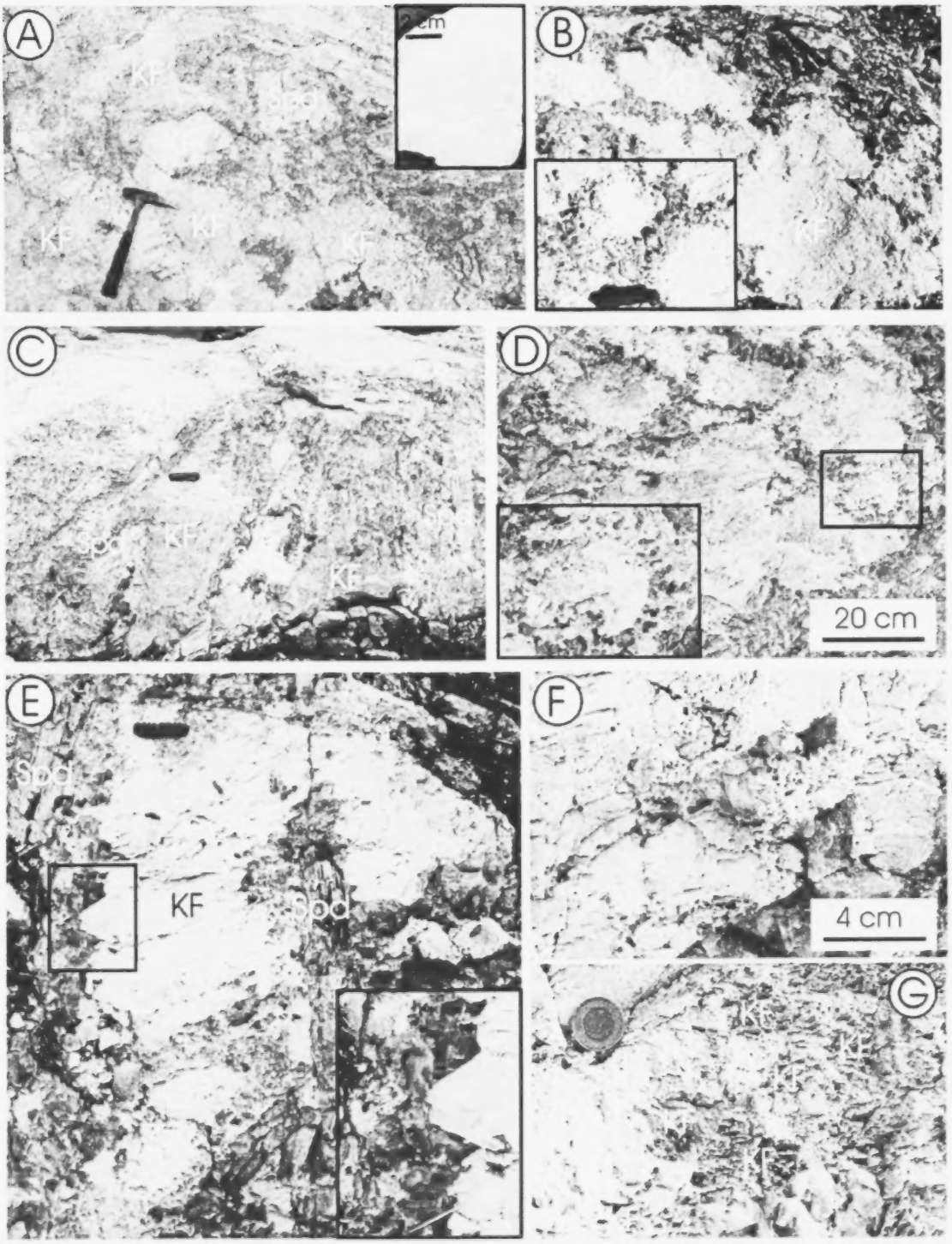
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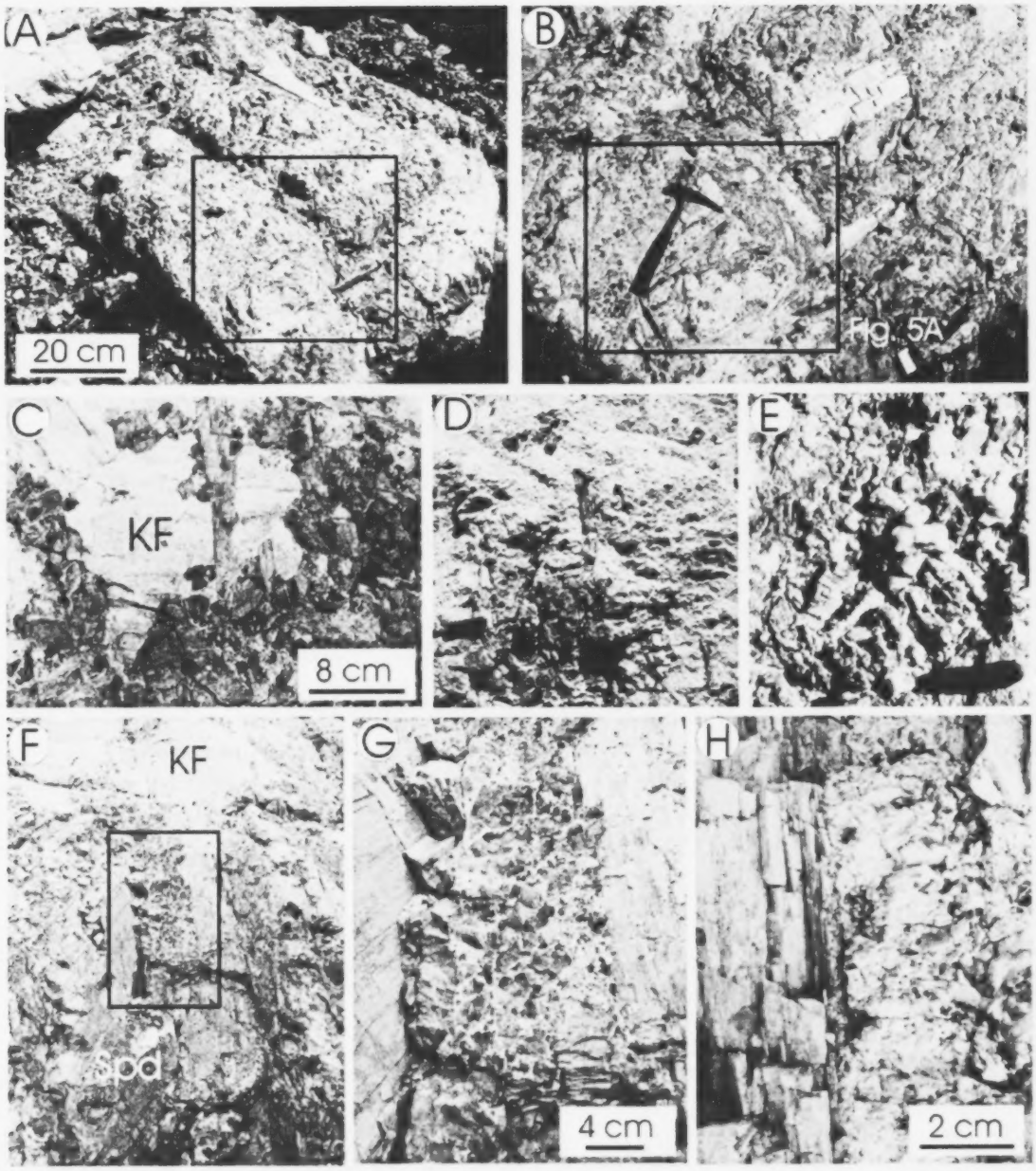


Figure 7. Outcrop photos showing features of spodumene (Spd) in southern pegmatite, Brazil Lake. Knife scale ca. 10 cm long. (A, B) Outcrop dominated by Spd megacrysts oriented perpendicular to contact of pegmatite. (C) Intergrowth of Spd and blocky K-feldspar (KF) at contact between zones enriched in these minerals. (D) Spd crystals penetrating KF megacryst, which is now albitized. (E) Intergrowth of Spd and quartz in beaded quartz texture zone between KF megacrysts. (F) Spd-rich zone at margin of pegmatite with blocky KF zone on top of it. Note that the Spd is oriented perpendicular to the contact. Box outlines area enlarged in next photo. (G) Close up of intergranular material between Spd megacrysts consisting of subhedral to euhedral quartz with albite and cleavelandite after earlier KF. (H) Close up of Spd against cleavelandite in albitized zone showing that the Spd was not affected by the metasomatism.

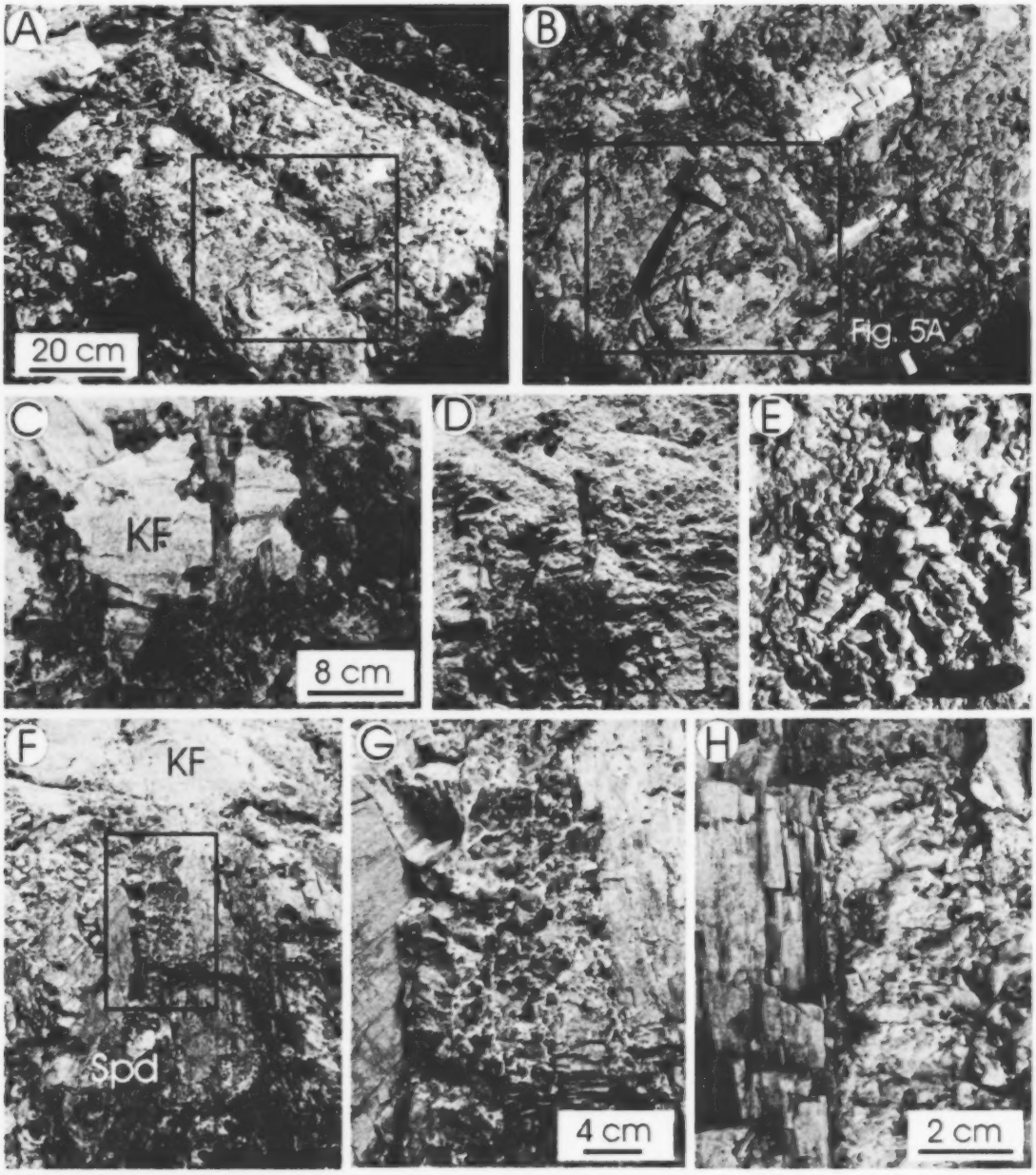


Figure 7. Outcrop photos showing features of spodumene (Spd) in southern pegmatite, Brazil Lake. Knife scale ca. 10 cm long. (A, B) Outcrop dominated by Spd megacrysts oriented perpendicular to contact of pegmatite. (C) Intergrowth of Spd and blocky K-feldspar (KF) at contact between zones enriched in these minerals. (D) Spd crystals penetrating KF megacryst, which is now albitized. (E) Intergrowth of Spd and quartz in beaded quartz texture zone between KF megacrysts. (F) Spd-rich zone at margin of pegmatite with blocky KF zone on top of it. Note that the Spd is oriented perpendicular to the contact. Box outlines area enlarged in next photo. (G) Close up of intergranular material between Spd megacrysts consisting of subhedral to euhedral quartz with albite and cleavelandite after earlier KF. (H) Close up of Spd against cleavelandite in albitized zone showing that the Spd was not affected by the metasomatism.

pegmatite prior to sodium metasomatism, which converted much K-feldspar to sacchroidal albite and cleavelandite. However, remnant areas of fresh K-feldspar remain, particularly in the southwestern part of the study area where BKF domains of beige to light orange occur. Cut slabs of this K-feldspar show perthitic textures with minor albite, consistent with bulk analysis (n=4) of $Or_{70-80}Ab_{30-20}$ (Fig. 9a) and a minimal An component (<0.02 wt. % CaO). These bulk analyses are similar to bulk compositions of K-feldspar from leucogranite-hosted pegmatites of the South Mountain Batholith and suggest primary compositions (Fig. 9b; Kontak *et al.*, 1995). Trace element chemistry (n=4) of the same K-feldspar separates indicates elevated Rb (3870 to 4870 ppm), but depleted Sr (17-75 ppm) and Ba (32-190 ppm) contents. Similar concentrations of these elements were also obtained by Hughes (1995) for K-feldspar concentrates (n=4) from the northern pegmatite, although he detected up to 5600 ppm Rb in one sample. Chondrite-normalized rare-earth element patterns are depleted compared to, for example, K-feldspar from pegmatites at East Kemptville and the Brenton Pluton and compare, instead, to patterns for K-feldspar from pegmatites in the most evolved parts of the SMB (Fig. 10). Phosphorus levels in the K-feldspar are low (<0.2 wt. % P_2O_5) and contrast with high levels (to 1.5 wt. %) in K-feldspar from pegmatites of the SMB (Kontak *et al.*, 1995).

Imaging of the freshest K-feldspar indicates typical flame perthite lamellae occur with no vestige of film perthite, as found, for example, in pegmatitic K-feldspar at Peggys Cove (Kontak *et al.*, 2002). Instead, coarser bleb perthite is more common (Fig. 11a) and pitted textures are not uncommon (Figs. 11a, b). Remnant patches of K-feldspar in albite domains (i.e. metasomatic rocks) are characterized by a very porous sieve texture (Figs. 11b, c) and secondary apatite is common (Fig. 11b). In detail, the porous texture is seen to consist of a network pattern with isolated domains of residual K-feldspar (Fig. 11c). The chemistry of the Or and Ab domains of K-feldspar indicates equilibrated compositions of Or_{90-100} and Ab_{100}, respectively (Fig. 9b), which reflect exchange down to below 300°C. In rare cases such remnant patches of K-feldspar are replaced by clay and Fe-Mg mica (i.e. chlorite phase). Traces of Fe, Cr, Ni and Cu phases, either as native elements or oxides, occur in the porous-textured areas (Fig. 11l). This type of mineralization is common in pegmatites and reflects a lack of sulphur in the melts and fluid (Černý, 1991b).

Spodumene

Spodumene is present as a very pure phase with megacrysts rarely containing mineral inclusions, although small quartz euhedra (<1 cm) locally occur along margins of grains. Spodumene has a glassy lustre and can be transparent; colours vary from whitish, beige, grey-blue to green and, rarely, clear. Prized gem varieties such as kunzite, heddenite and triphane have not been observed. Where fractures are present or deformation induced recrystallization, alteration to muscovite or a green phase (chlorite ?) is found. However, where metasomatic albite occurs after K-feldspar, the spodumene appears unaffected by the process (Figs. 7d, h). Although few thin sections of spodumene from the southern outcrop have been observed, it is noted that Hughes (1995) mentions that alteration of spodumene is common in the northern pegmatite, with pseudomorphic replacement by albite, muscovite, K-feldspar, cookite, and chlorite. In addition, a spodumene-quartz intergrowth noted by Hughes (1995) has also been observed in one sample, which may represent spodumene-quartz intergrowth formed after petalite (e.g. Černý and Ferguson, 1972). Compositions of spodumene approximate a pure end member, with minor Fe at levels <0.3 wt. % FeO and trace Mn (177 to 610 ppm) (Hughes, 1995).

Quartz

Quartz varies considerably in its habit and colour within the pegmatite. Rarely is it subhedral to euhedral where intergrown with K-feldspar (Fig. 6e) or as part of the BQT zones, but instead anhedral forms are the most common and this is, in part, a result of post-crystallization deformation (Figs. 8d, e). Where fractured or brecciated, quartz is surrounded and invaded by cleavelandite, often with a comb or radial texture about the quartz, or intergrown with it, which suggests continued

crystallization. Although most quartz is translucent to transparent, colours range from cloudy white through clear to black, with no consistent pattern observed (Fig. 8), except that deformed quartz is generally darker. No chemical analyses are available for quartz, but slabbed samples indicate that micro-inclusions of apatite and Ta-Nb oxides are locally common.

Albite

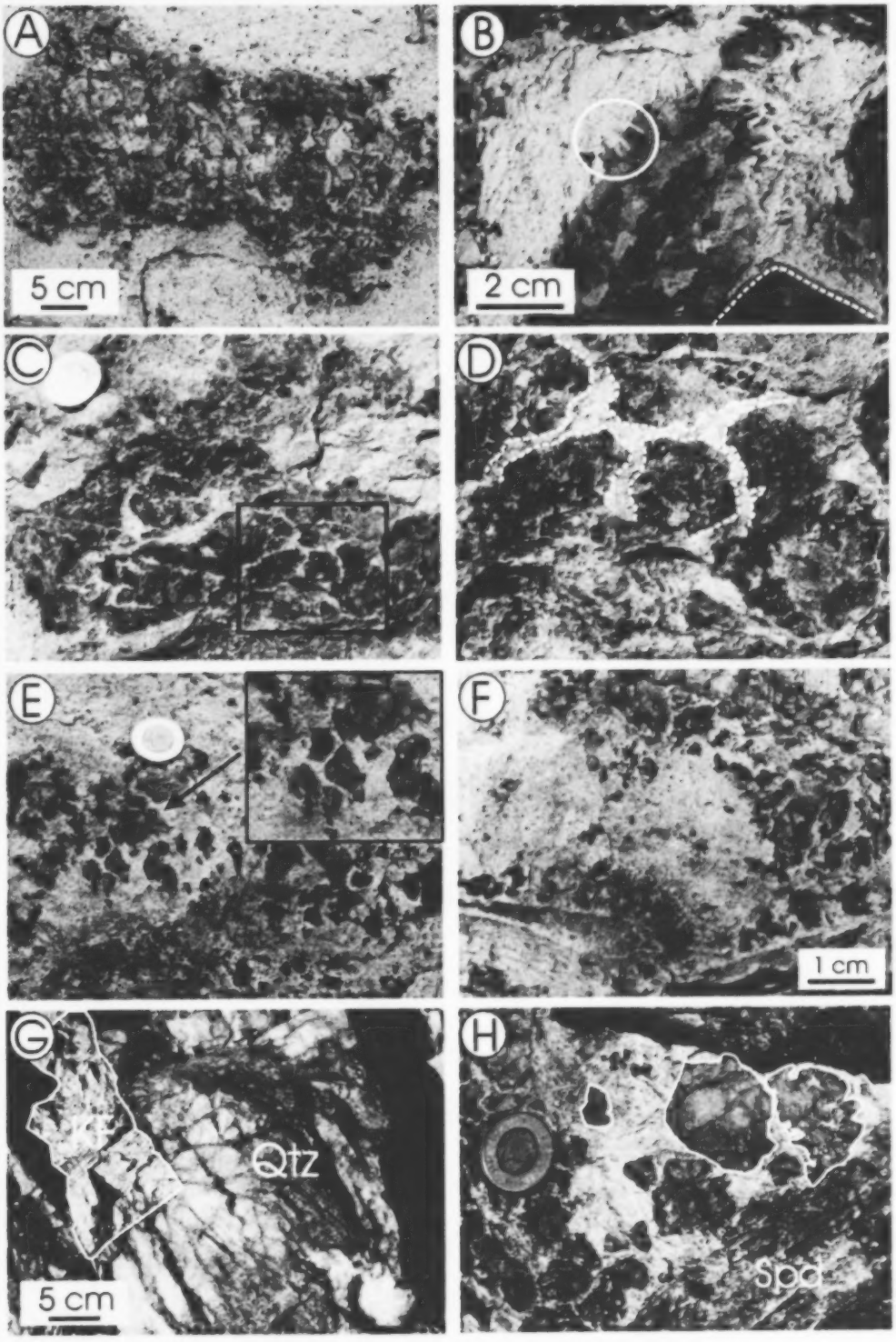
Two varieties of albite occur, a fine-grained sacchroidal-textured type, and platy to acicular cleavelandite; both types are of Ab_{100} composition (Fig. 9). The former occurs as a replacement of blocky K-feldspar (Figs. 6b, g), which has a fabric defined by subparallel laths in thin section; this fabric is inferred to be of syntectonic origin. In some cases the albite is crystal clear and lines cavities in metasomatized BKF zones. Imaging indicates the albite is clear to pitted in texture with such grains adjacent each other (Figs. 11d, e) and often they terminate within voids (Fig. 11d). The albite also contains disseminated euhedra of apatite (Figs. 11d, e). Cleavelandite occurs as euhedral to subhedral grains in a variety of settings that represent various types of metasomatism: (1) replacement, either along linear to irregular fractures cross-cutting K-feldspar megacrysts (Fig. 6f), (2) patches within or entirely replacing K-feldspar, and (3) intergrown with quartz as part of intergranular areas to coarse spodumene or K-feldspar. All types of albite generally contain disseminated fine-grained apatite and Nb-Ta oxides, and slabbed samples of the massive albite indicate that in some cases these minerals can be abundant. Chemical analysis of two albite pods indicated trace amounts of Rb (10-65 ppm) and Sr (13-175 ppm); other elements analyzed were at very low levels (e.g. Li, Nb, Ta, Cs, Ba).

Muscovite

Muscovite in the southern pegmatite is both of primary and secondary origin, based on its habit and textural relationship with other phases. Primary muscovite is part of the beaded quartz texture or leucrogranite zones that surround megacrysts of BKF, leucogranite around coarse spodumene, and part of the coarse leucrogranite matrix. The primary muscovite, estimated at <1% modally, occurs as coarse books <1-2 cm and is mostly light brown to clear. In contrast, secondary muscovite is generally associated with albitized zones, either after BKF or in beaded quartz texture, or occurring as fracture coatings or veins <5-10 mm wide. Boulders of massive (i.e 80-90%) muscovite have been observed, but such material has not been seen *in situ*. The secondary muscovite is fine- to coarse-grained, and may be silvery, brown, clear or green.

Muscovite is close to its end member in composition, with minor Fe (to 1.0 wt. % FeO) and Na (to 0.4 wt. % Na_2O), as seen in the ternary (M^{2+}-Al-Si) plot of Monier and Robert (1986; Fig. 12). Compositions for a variety of textural types are all similar and suggest high temperature (i.e. 600°C) equilibration, regardless of paragenesis. Bulk analysis of muscovite from massive pods of the same material (n=3) indicates high abundances of Rb (3000-4600 ppm), Nb (120-160 ppm), and Ta (211-61 ppm). Hutchinson (1982) also noted high contents of Rb in muscovite from the northern pegmatite.

Figure 8. (next page) Outcrop photos showing features of quartz in Brazil Lake pegmatite. Knife scale ca. 10 cm long. (A) Close up of the beaded quartz texture (BQT) developed between blocky K-feldspar (KF) megacrysts. The quartz is intergrown with spodumene and albite (after KF). (B) Translucent quartz intergrown with secondary cleavelandite. Note the penetrating nature of some cleavelandite crystals (circled) and euhedral outline of the quartz (dashed line). (C, D) Megacryst of quartz among blocky KF. This quartz is typically dark grey to black in color and has a jig saw pattern possibly due to autobrecciation, as highlighted by the outline in dashed white line. Note that albite occurs as part of the intergranular matrix and some cleavelandite is developed that is intergrown with the quartz. (E) Anhedral quartz disseminated within mixture of fine-grained albite and acicular cleavelandite after KF megacryst (slightly darker areas are patches of orange KF). Inset shows possible autobrecciated quartz grain. (F) Similar feature as in previous photo, but here there is apatite intergrown with the angular quartz grains and in the fine-grained albite. (G) Intergrowth of coarse smoky quartz and euhedral KF in quartz-rich part of pegmatite near contact. (H) Intergrowth of quartz and albite (after KF) in intergranular matrix to Spd megacrysts. Some of the quartz grains have been traced to show the variation in habit from euhedral to anhedral(where ruptured) with albite filling what was once open space between the quartz grains.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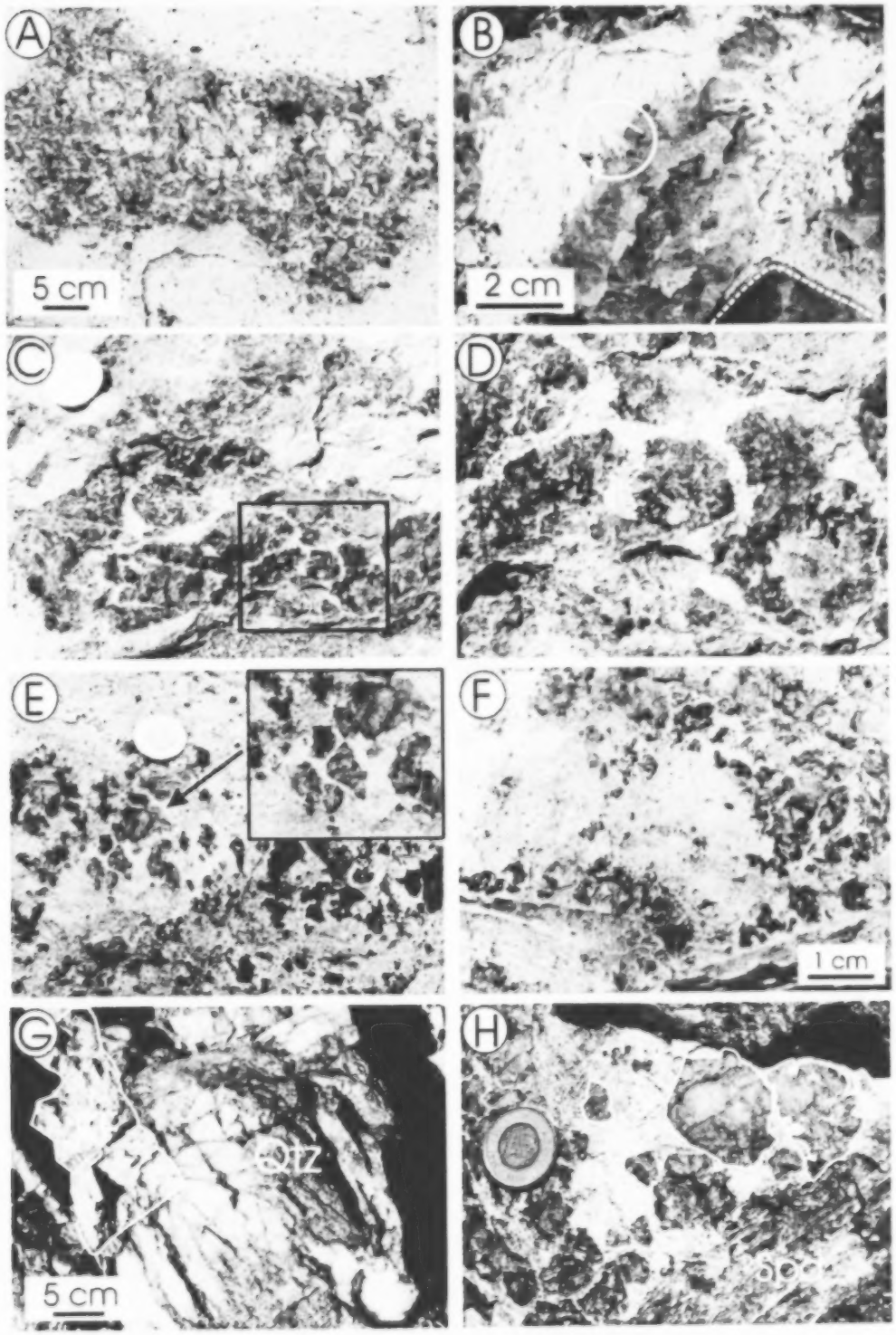
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Accessory Minerals

Accessory mineral phases include tourmaline, apatite, garnet, beryl, chlorite, Ta-Nb oxides, carbonate, triplite, amblygonite, cassiterite, wolframite, sphalerite, zeolite, zircon, epidote, clay and a variety of phosphate phases. The chemistry and distribution of these phases are currently being studied; only some of the minerals are discussed here and a more complete description of these phases is in preparation.

Tourmaline occurs as brown-black to green-brown and dark blue, centimetre-size euhedra within altered wallrock inclusions (i.e. amphibolites) along the margin of the pegmatite and also as smaller grains (<0.5 mm) in amphibolites adjacent to the pegmatite. The grains are both homogeneous or complexly zoned. Preliminary analysis of pegmatite-hosted tourmaline indicates dravite-schorl compositions with some extreme Fe enrichment noted (Fig. 13). Trends of the chemical data are typical of pegmatitic tourmaline originating from contamination due to pegmatite-host rock interaction (Fig. 13; Tindle *et al.*, 2002). Hughes (1995) has also identified elbaite and indicolite (Na+Li type) in the northern pegmatite.

Garnet occurs as multi-centimetre, subhedral to euhedral grains within albite-rich zones, with or without secondary muscovite. The garnet often has subgrain development due to fracture-related deformation. Several grains have been analyzed (this study and Hughes, 1995) revealing a uniform chemistry dominated by Fe and Mn with a general composition of $Alm_{20-28}Spess_{72-80}$.

Beryl crystals, either as isolated grains or in clusters, are clear to pale green, <3-4 cm in size, and occur along the eastern side of the pegmatite. No chemical data are yet available for the beryl. Of the grains observed, the internal fracturing and faint green colour precludes their use as gem material (B. Wilson, personal communication, 2003).

Apatite occurs as euhedral to anhedral macro- (<1-2 cm) or micro-crystals (mm size) within leucogranite areas, intergrown with cleavelandite

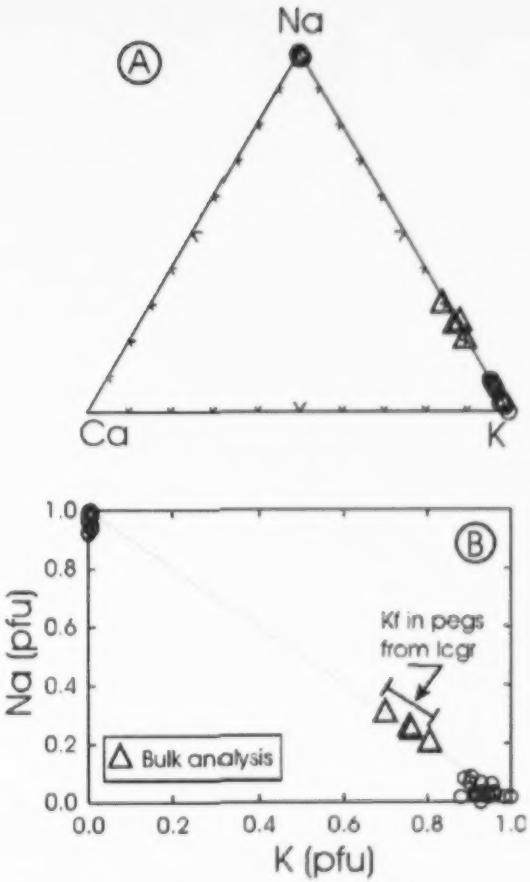


Figure 9. Electron microprobe (circles) and bulk analysis (triangles) of feldspar phases in Brazil Lake pegmatite plotted in ternary (Ca-Na-K) and binary (Na-K) diagrams. Note that it is the cationic proportions, based on 8 oxygens per formula unit (pfu), that are plotted in the diagrams. The range of KF in pegmatites in lcgr refers to samples from the South Mountain Batholith, as discussed in the text.

or disseminated in sacchroidal albite after BKF. The smaller grains are also common along fractures in deformed quartz. Fine-grained apatite euhedra intergrown with albite may locally be abundant (Fig. 11f) and are complexly zoned (inset in Fig. 11f). This apatite may be inclusion rich, including carbonates and sulphides (Fig. 11g). Apatite also occurs along fractures and fills voids in albite (Fig. 11h), and pitted textures occur associated with a second generation, Mn-rich apatite (Fig. 11i). Micrograins of euhedral to anhedral apatite occur as disseminations within

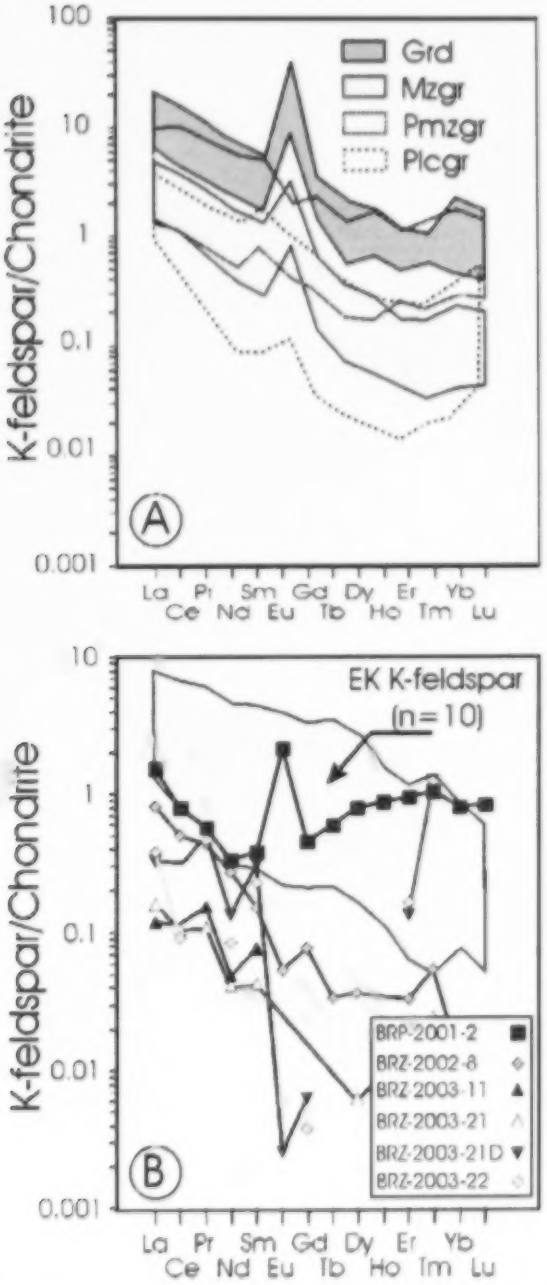


Figure 10. Chondrite-normalized rare-earth element diagrams for K-feldspar (KF) separates from southern pegmatite, Brazil Lake. (A) Compiled data set for KF separates from the South Mountain Batholith (Kontak and Martin, 1997) showing general decrease in REE with fractionation. Grd=granodiorite, Mzgr=monzogranite, Pmzgr=pegmatite in monzogranite, Plcgr=pegmatite in leucogranite. (B) KF from Brazil Lake pegmatite compared to field for KF from East Kemptville pegmatites (Kontak *et al.*, 2001). Sample BRP-2001-2 is from the pegmatite in the Brenton Pluton and BRZ-2003-21D is a duplicate of sample BRZ-2003-21.

K-feldsparr (Fig. 11b) and secondary albite, (Fig. 11d) or along fractures in quartz and albite. Similar euhedral apatite crystals are also common in pitted K-feldspar and albite (Fig. 11e).

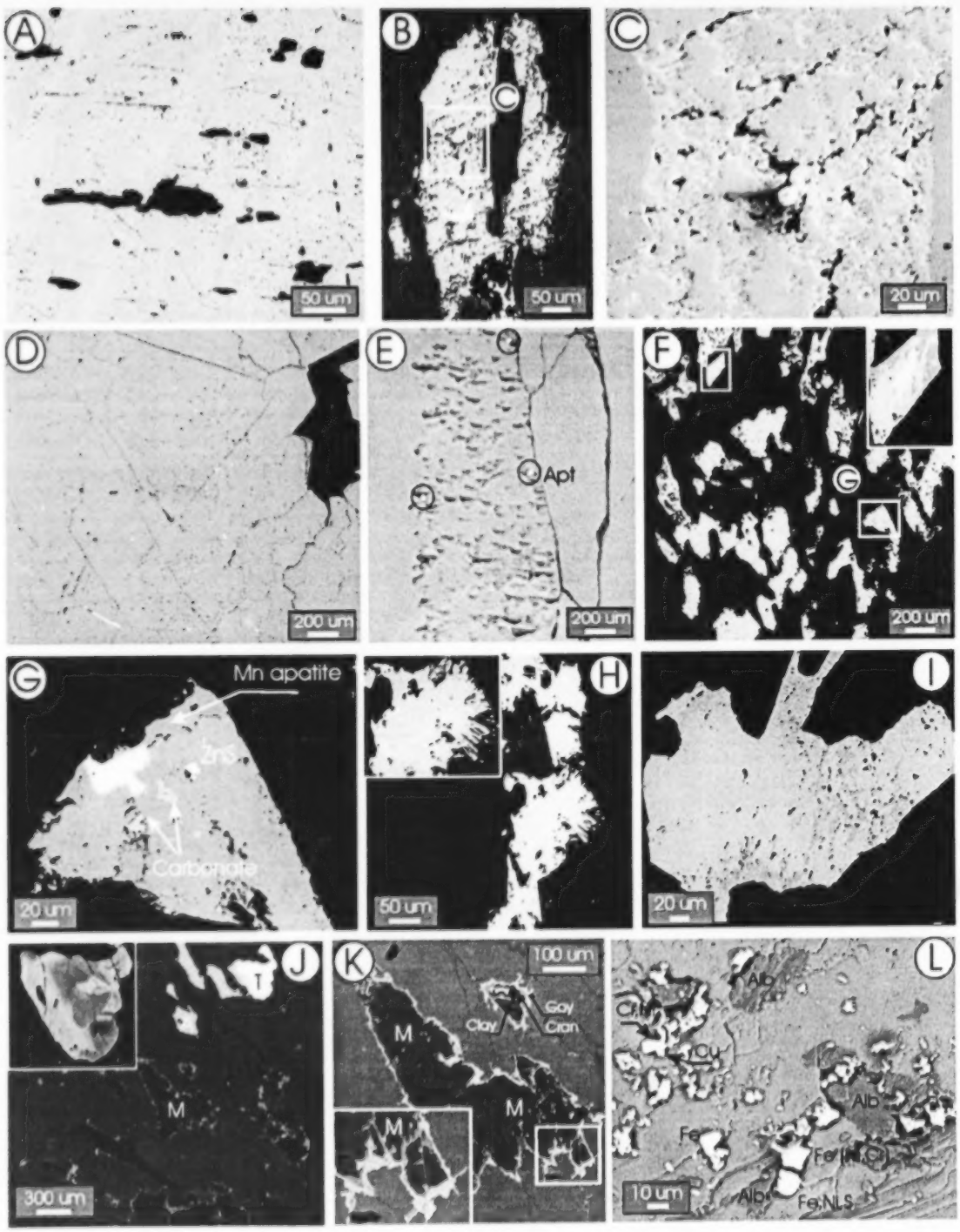
Compositions of apatite vary considerably and grains may be homogeneous to complexly zoned reflecting continued re-equilibration with a fluid. The early, coarser-grained and subhedral to euhedral apatite is generally Mn poor and contains several wt. % Cl. In contrast, texturally late stage and finer-grained apatite, or apatite overgrowing earlier apatite (Fig. 11g, i), is enriched in Mn via the substitution of Mn=Ca and up to 15-18 wt. % MnO occurs. The Mn-rich apatite is Cl deficient and, therefore, inferred to be hydroxylapatite. Hughes (1995) reports the occurrence of fluorapatites with 4 wt. % F in albitic aplite zones.

Tantalite-columbite occurs within the albite-rich zones, along fractures in quartz and in leucogranite areas. Most of this oxide mineralization shows a spatial association with albite, an observation that is supported by whole-rock chemistry discussed below. Chemical analysis of selected grains indicates highly variable Ta:Nb ratios, although most are enriched in Nb>Ta. Grains vary from homogeneous to intricately zoned (Inset in Fig. 11j). Ongoing work is required to sort out the nature of this oxide mineralization, and the origin of the Ta:Nb variability.

A complex group of phosphate phases occurs, including montebrasite, goyazite, crandallite, lithiophillite and fillowite. The most common phase is montebrasite which occurs in fine-grained sacchroidal albite as a subhedral to euhedral phase (Fig. 11k), but Hughes (1995) also reports it within coarse K-feldspar. The montebrasite has a uniform composition [LiAl PO_4(OH)] and its F-rich equivalent, amblygonite, has not been found in the pegmatite. Montebrasite is invariably altered to crandallite and then goyazite, which record the low temperature (300°C) alteration of the precursor phosphate phase. In some cases the montebrasite is also altered to an unidentified clay mineral (Al-Si phase from EDS spectra).

In a few rare cases, native elements and oxide phases of Fe, Cr, Ni and Cu were observed in K-feldspar associated with secondary albite (Fig. 11l). Determining the nature and origin of this material requires further work, but such phases are not uncommon in pegmatites due to the lack of sulphur to combine with these elements to form sulphide phases (Černý, 1991b).

Figure 11. (next page) Electron microprobe images of samples from Brazil Lake pegmatite. All images except C and L are back scattered electron(BSE) images where the higher the average atomic number of the phase the brighter it is (e.g., see tantalite (T) in Fig. 11J hosted by albite). Images in C and L are secondary electron images (SEI) that reflect the surface topography of samples (e.g., holes, defects, etc.). (A) K-feldspar (KF) host with albite blebs. The KF is characterized by a pitted texture with intervening areas free of pits. (B) Residual grain of KF in albite (dark background). Note the porous nature of the KF and presence of anhedral apatite grains (bright phases at bottom and top) in it. Area in box enlarged in C. (C) SEI of part of KF in previous figure showing the ver porous texture of the grain that relates to Na metasomatism of the KF. (D) Albite with pitted texture in places, disseminated grains of apatite (bright phases), and euhedral grains that terminate in the open space. (E) Close up of albite with pitted texture with rare apatite (Apt) filling the pores. (F) Apatite grains of euhedral to subhedral shape in albite. Note that there is dissolution along the margins of some grains and in detail they contain micro-inclusions and are chemically heterogeneous. Inset shows close up of apatite grain with large variation in Mn content (bright areas have up to 18 wt. % MnO). (G) Close up of apatite grain from previous image showing inclusions of Fe-poor sphalerite (ZnS) and carbonate (Mn-bearing) in Mn-poor apatite that is rimmed by Mn-rich apatite. (H) Apatite filling open space in albite host. Note the euhedral terminations of the apatite indicating it once filled a void. Inset shows the apatite euhedra and small inclusions of an Fe oxide phase. (I) Apatite grain of uniform composition with second generation Mn-bearing apatite along fractures that are lined with pitted texture. (J) Albite hosting montebrasite (M), apatite (A) and tantalite (T) phases. Inset diagram shows tantalite grain in high contrast mode to emphasize the zoning in Ta and Nb ratio. (K) Close up of montebrasite grain in previous image to illustrate the secondary alteration of this phase to crandallite (Cran), goyazite (Goy) and clay. Inset is enlargement of part of the big grain to show the secondary phases. (L) Chip of KF with inclusions of albite blebs (Alb) and various mixtures of Fe, Ni, Cr oxides and Cu oxide phase. Note that only minor amounts of S were detected in the analysis.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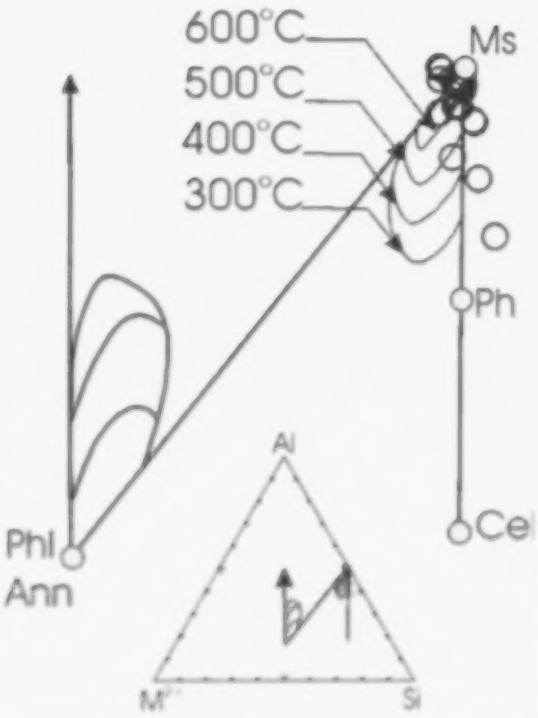

Figure 12. Electron microprobe analysis of muscovite from Brazil Lake pegmatite plotted in Monier and Robert's (1986) ternary diagram with isotherms. Abbreviations are Cel=celadonite, Ph=phengite, Ms=muscovite, Ann=annite, Phl=phlogopite.

Whole-rock Chemistry

A database of 250 whole-rock geochemical analyses has been generated by Gwalia Resources of Australia and Champlain Resources Inc. Samples of 0.4-1.8 m long core intervals, although the majority were about 1 m long, were assayed for major and trace elements. Only some salient highlights of these data are discussed below; a more detailed assessment of the results is in preparation. The following points are noted with reference to Figures 14 and 15.

(1) As expected, there is a negative correlation of both lithium and potassium with sodium.
(2) Both calcium and phosphorus show a positive correlation with sodium, thus confirming the association of phosphates, in particular apatite, with albite-rich zones. Manganese (not shown) also shows a positive correlation with phosphorus.
(3) Enrichment of both Ta and Sn are associated with increasing sodium abundance.
(4) There is no association of Rb with sodium (not shown) or phosphorus enrichment. Instead, Rb is strongly correlated with potassium and occurs in either K-feldspar or muscovite based on the mineral chemistry discussed above.

Structural Features of the Southern Pegmatite

Detailed mapping of structural elements of the pegmatite is incomplete, but a few pertinent observations are noted.

(1) The overall features of the pegmatite indicate that a single stage of open-space infilling occurred, such that the pegmatitic melt was injected into a dilatant zone in the host rocks. The orientation and size of the megacrysts indicate a single dilation event, rather than multiple injections of magma.
(2) Quartz megacrysts are often oval or elliptical, but subhedral outlines may reflect the original shape of megacrysts (Fig. 8c). These grains were subsequently ruptured during deformation (Figs. 8d, e) and, in certain cases, the subgrains have serrated or irregular outlines and the intervening space is filled with oriented albite grains (Fig. 8d). These textures suggest that pegmatitic melt was injected into an active shear zone environment, and that the pegmatite was subjected to deformation prior to complete crystallization.
(3) Shear zones oriented subparallel to the pegmatite-wallrock contact occur throughout and are manifest by flattened quartz megacrysts, kinked spodumene and shear fabrics in muscovite-rich areas. The fabric is generally oriented northeasterly with a subvertical dip, and the kink folds have subvertical axes.

Age of the Brazil Lake Pegmatite

The age of the Brazil Lake pegmatite has previously been constrained by field relationships, with a minimum age equivalent to the host White

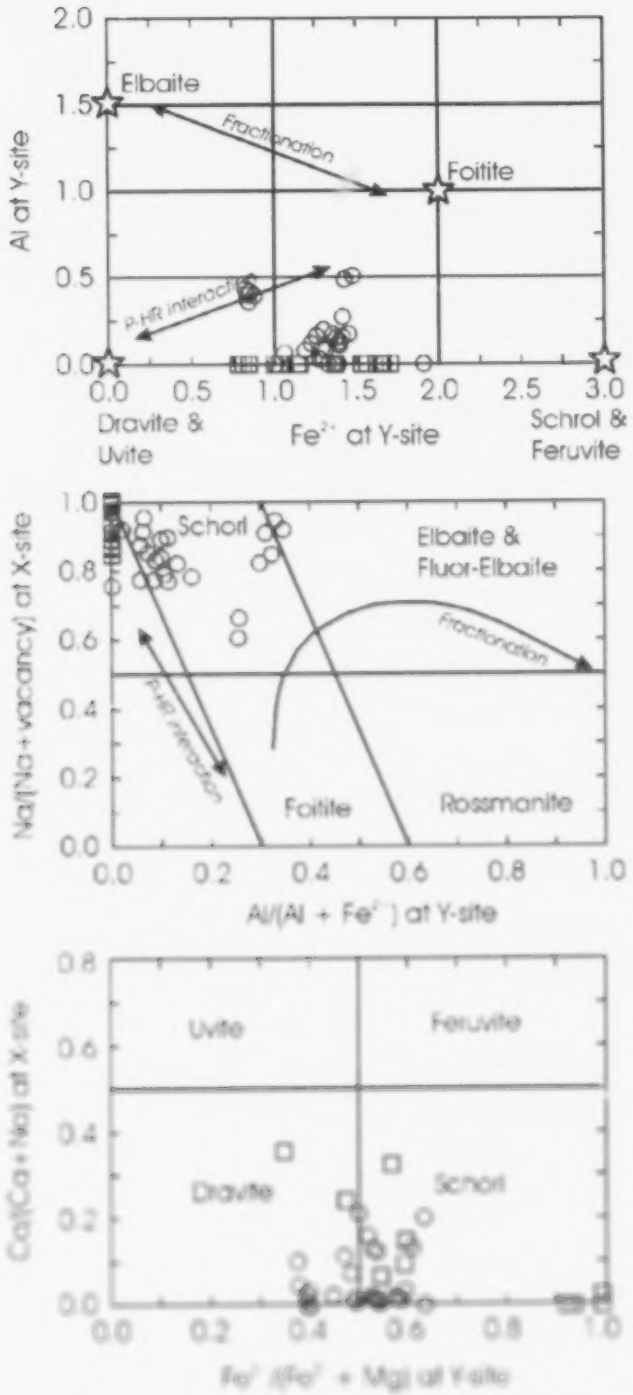

Figure 18. Electron microprobe analyses of tourmaline from Brazil Lake pegmatite in binary plots with fields for tourmaline classification (after Trindade *et al.*, 2002). The terms P-HR refers to pegmatite-host rock interaction and reflects contamination. Circles are from this work and squares are from Hughes (1998).

Rock Formation and a minimum age being the time of the deformation that affected the pegmatite. However, the presence of both Acadian and Alleghanian deformation in the region (White *et al.*, 2001) makes it difficult to infer a minimum age for the pegmatite. In order to resolve the absolute age of pegmatite formation, samples from the southern pegmatite were selected for U/Pb (tantalite), Re-Os (molybdenite) and Ar/Ar (muscovite) analysis. The results will be discussed in detail elsewhere (Kontak *et al.*, in prep.), thus only a summary is given below.

Analysis of a single fraction of separated, euhedral, columbite-tantalite grains disseminated within an albite-spodumene-muscovite assemblage, part of a blocky K-feldspar zone, yielded a concordant U/Pb age of 378 ± 1 Ma. Three Re-Os age determinations for various size fractions of molybdenite from wallrock quartzite on the northwest side of the southern pegmatite yielded ages of 351.7, 351.9 and 354.2 Ma (all ± 2.5 Ma). Finally, several Ar/Ar spot laser ages for a coarse, euhedral muscovite flake, of primary magmatic origin, from a beaded quartz-textured zone gave ages of 318 to 348 Ma, with the former from the rim and the latter from the core of the grain.

The aforementioned ages indicate that the time of pegmatite formation is constrained by the U/Pb tantalite age, which coincidently is similar to a U/Pb age of 380 Ma for the nearby South Mountain Batholith (Kontak *et al.*, 2003). The ca. 353 Ma Re-Os molybdenum age is similar to a U/Pb age of 357 Ma for the Wedgeport Pluton south of Yarmouth (White *et al.*, 2004), whereas the Ar/Ar ages approximate the time of the Alleghanian deformation in the area (e.g. Culshaw and Reynolds, 1997).

Discussion

Implications of the Age of Pegmatite Formation

The age reported here for the BLP is 378 Ma, which is indistinguishable from the time of emplacement of the South Mountain Batholith (SMB) (Kontak *et al.*, 2003; Carruzzo *et al.*, 2004).

Although the SMB is located some 20-25 km from the Brazil Lake area, a distance considered to be excessive for transport of a pegmatite melt from a fertile, progenitor granite (Baker, 1998), this does not preclude the possibility that an unexposed granite was the source. As noted by Černý (1991b), there is no plausible model for rare-element pegmatite genesis other than a magmatic one, thus a granitic source is assumed and the 378 Ma age is very suggestive that granite underlies the Brazil Lake area. Relevant to this argument is the presence of numerous tin and base metal showings throughout the Meguma Group metasedimentary rocks east of the study area (Chatterjee, 1983; Kontak *et al.*, 1990) and on strike with the East Kemptville tin deposit. This mineralization likely originated in underlying granite, such as occurs at the Kempt Snare Lake (Soehl, 1988) and Duck Pond (Pitrie and Richardson, 1989) mineralized centres. As noted by Dostal and Chatterjee (1995), the Davis Lake Pluton of the SMB is strongly fractionated toward the west and the nature of contours for a variety of elements (e.g. Rb, Li, F) and ratios (e.g. K/Rb) suggests that there may be highly-fractionated granitic phases beneath the veneer of sediments overlying the continuation of this pluton, which fed the mineralization noted above. Thus, it may also be possible that one of these centres is also the fertile source of the Li-rich melt that gave rise to the Brazil Lake pegmatites.

P-T Conditions of Emplacement of the Brazil Lake Pegmatite

The pressure-temperature (P-T) conditions of pegmatite formation are relevant to petrogenetic modeling of the Brazil Lake pegmatite. The constraints imposed on P-T conditions are: (1) presence of primary muscovite in beaded quartz texture material; (2) occurrence of primary spodumene as the dominant sink for Li rather than petalite or eucryptite. However, the presence of rare spodumene-quartz intergrowth (this study and Hughes, 1995) suggests that rare early crystallization of petalite may have occurred locally, although alternate interpretations of this texture are possible; (3) occurrence of aqueous fluid inclusions in spodumene with homogenization temperatures of >315°C and salinities of 5 wt. % equivalent NaCl (Hughes, 1995); (4) solidus of Li-

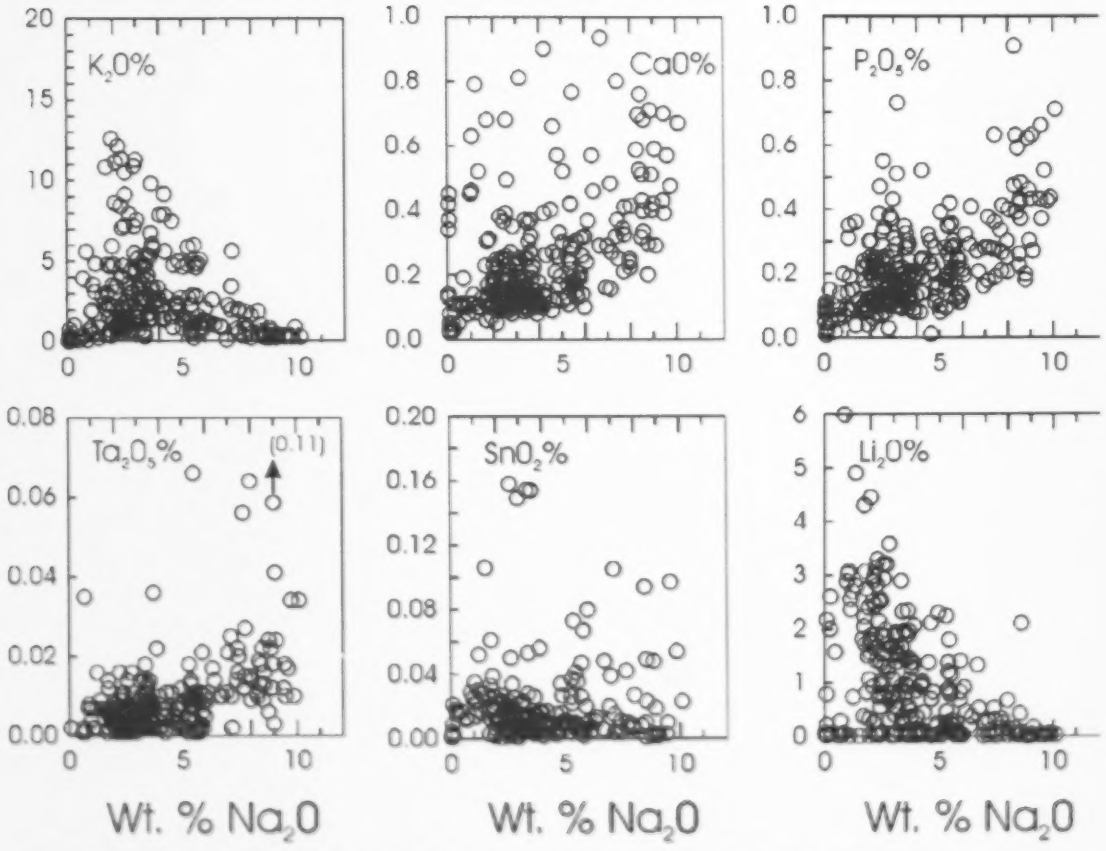

Figure 14. Whole-rock geochemical plots for pegmatite samples from Brazil Lake. See text for discussion.

rich felsic melt (Martin, 1983). Using the stability of the phase assemblages and projecting the isochore for a 5 wt. % equivalent NaCl fluid, an estimated P-T path for emplacement and crystallization of the pegmatite is derived, which indicates initial emplacement at ca. 3.5–4 kbar and near 600°C, which is comparable to that inferred for the spodumene-bearing Harding pegmatite, New Mexico (London, 1984). These conditions compare to the estimated level of emplacement of the SMB of 3.5 kbar (Raeside and Mahoney, 1996) and granite and pegmatite formation at the East Kemptville tin deposit of 3.5–4.0 kbar (Halter and Williams-Jones, 1999; Kontak *et al.*, 2001).

Metasomatism (?) in the Brazil Lake Pegmatite

The origin of the voluminous albitic or mica-rich units in rare-element pegmatites is sometimes equivocal, but of economic interest because of the concentrations of Be, Li, Rb, Cs, Nb, Ta, Sn and U (London, 1990). In the case of the BLP, there is a clear association of rare elements with sodic enrichment (Figs. 8f, 14, 15). Whereas small amounts of metasomatism are easily explained because of pseudomorphic replacement textures, the large areas underlain by albite/cleavelandite or mica are more equivocal since such textures are lacking, although Soviet geologists have long argued for a metasomatic origin (e.g. Ginzburg, 1960; Beus, 1960). As noted by others, the large Li-bearing minerals, in this case spodumene, often project into the albite areas with no evidence of alteration (e.g. Figs. 8c, d). However, in these cases the fact that such Li minerals provide the substrate for nucleation of coarse radiating cleavelandite, of assumed magmatic origin, is used to argue for a

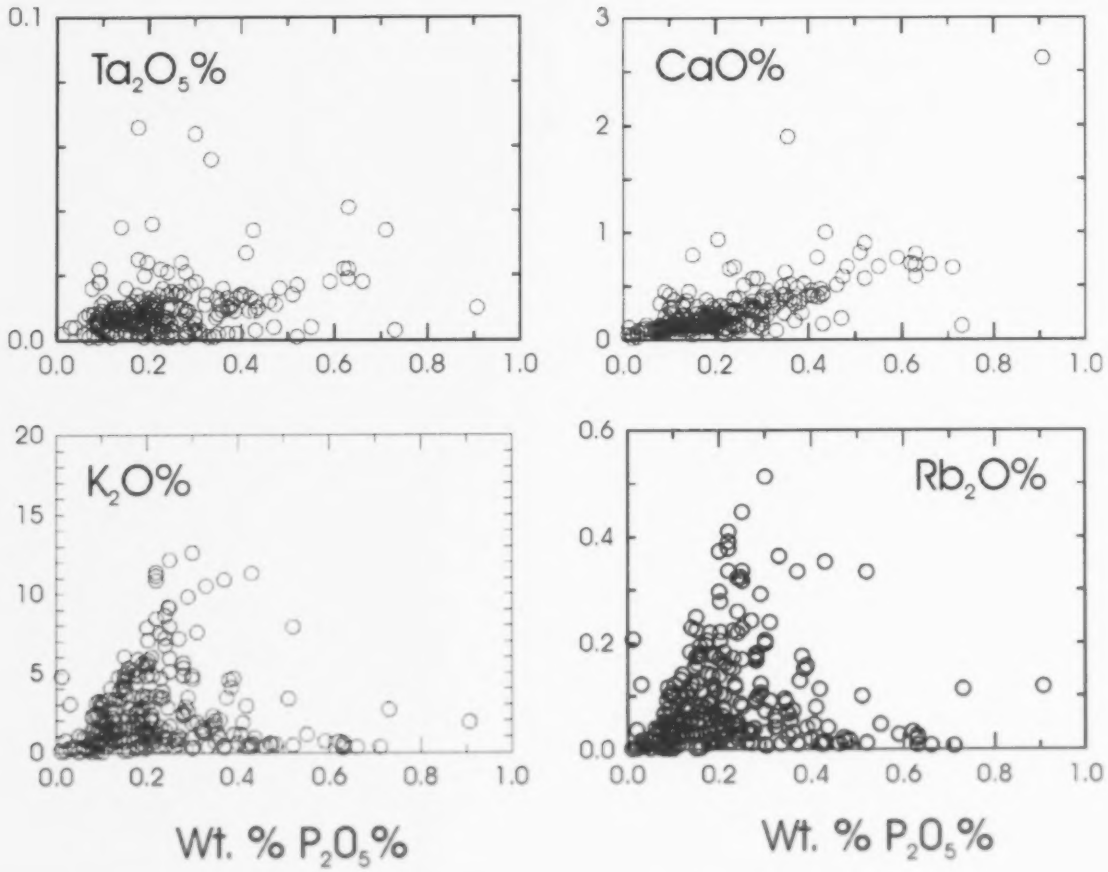

Figure 15. Whole-rock geochemical plots for pegmatite samples from Brazil Lake. See text for discussion.

late, residual magmatic origin for the spodumene, along with the coexisting quartz and mica (Jahns and Tuttle, 1963; Jahns and Burnham, 1969; London 1990). Although the petrological observations discussed above are interpreted to favor a metasomatic origin for albite-rich zones in the BLP, both sacchroidal albite and cleavelandite, an alternative model presented by London (1990) is discussed below.

London (1990) explains that the inferred late alkali-sodic metasomatic units (e.g. albite-mica zones) were related to formation of a late solution-melt, as represented by silicate-rich fluid inclusions found in pegmatites (e.g. London, 1986b, c). The sudden formation of ore-bearing albite-mica zones, according to London (1990), occur due to sudden vapor saturation and the concomitant loss of boron and other volatiles, which suddenly raises the solidus temperature of the residual melt and thereby promotes crystallization (i.e. boron quench model, London, 1987). Upon crystallization of these melts, as bodies of albite ± mica and quartz, the exsolved aqueous vapor phase, formed from the elements not conserved by the crystalizing components, promotes the metasomatism of adjacent areas. Formation of the exsolved vapor also results in extensive fracturing of the pegmatite, which leads to an open bimetasomatic exchange between pegmatite and wallrock, as manifest, for example, by the presence of exomorphic tourmaline in the host rock.

The origin of the extensive albitic zones in the

Brazil Lake pegmatite requires additional work to resolve; however, the presence of these zones is emphasized for two reasons: (1) such zones destroy the blocky K-feldspar areas which, due to their high rubidium content, are a valued industrial mineral; and (2) the albitic zones are enriched in muscovite and also rare elements (e.g. Ta, Nb). Thus, the recognition of such zones and their extent is relevant to exploitation of these pegmatites and future work will address this issue.

Exploration Potential for Li-rich Pegmatite in the Brazil Lake Area

Exploration potential in the Brazil Lake area is inferred based on analogies with other rare-element pegmatite fields globally, where numerous pegmatites occur over large areas, some with considerable strike length (e.g. Černý, 1991b). Often these pegmatites are laterally zoned with LCT types generally distal from the fertile granite source, although the source is not always identified (e.g. Little Nahanni pegmatite field; Groat *et al.*, 2003). Excellent examples of such fields occur in, for example, the Superior Province of Canada (Breaks and Moore, 1992) and the Wodgina pegmatite district of the Pilbara Craton of western Australia (Sweetapple and Collins, 2002). This latter area, with some of the world's largest reserves of Ta (-Sn), is of particular relevance because of many similarities between it and the Brazil Lake pegmatite and evolved Davis Lake pluton of the South Mountain Batholith.

The occurrence of the highly-evolved and chemically-zoned Davis Lake Pluton (Dostal and Chatterjee, 1995) at the western end of the SMB, with all the attributes of a fertile granite related to LCT pegmatite fields (Černý, 1991a), is considered potentially significant. As already noted, there are numerous tin and base-metal occurrences between the termination of this pluton and the BLP and a semi-continuous boulder terrain of pegmatite float (D. Black, personal communication, 2003). In addition, along the western edge of the most evolved part of the Davis Lake Pluton southwest of the East Kemptville tin deposit, small centres of Ta-Nb occur in coarse-grained, albite-topaz - rich rocks. Collectively, both the style and abundance of lithophile-element mineralization suggest that fertile granites underlie the metasedimentary landscape, and that the Brazil Lake pegmatite is probably related to one of these fertile intrusions, as suggested for the pegmatite fields in the Wodgina district of Australia (Sweetapple and Collins, 2002).

As discussed by London (1990), the absence of early phenocrystic phases in rare-element pegmatites, including the BLP here, indicates that the pegmatites were emplaced as already fractionated melts rather than evolving *in situ*. This implies, therefore, that there should be an along-strike variation in the mineralogy and chemistry that can be used as an exploration guide. Pegmatite fields can be characterized by both unidirectional or concentric zonation; however, this zonation style can be discerned by using the mineralogy (e.g. beryl versus spodumene rich; Breaks and Moore, 1992) and mineral chemistry (e.g., K/Rb, K/Cs of BKF; Černý *et al.*, 1985) to define the type of zonation. With such limited outcrop as characterizes the Brazil Lake area this approach could prove useful.

Finally, local control on the occurrence of the Brazil Lake pegmatite remains unresolved. However, in many pegmatite fields, structure is considered to be a dominant feature controlling the locus of intrusion (Černý, 1991b). Future work will focus on the regional geology and potential influence of a dominant structural feature that may have localized the pegmatitic melt. It is, therefore, relevant to note that the mineralization at East Kemptville lies within a regional shear zone (East Kemptville-East Dalhousie Fault Zone; Horne *et al.*, 1992) and greisen formation was structurally controlled.

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Geoscience Editing and Publishing

D. R. MacDonald, B. L. MacDonald and J. S. Saunders

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The following publications were released in 2003:

Contribution Series

CS ME 2003-1 Nitrogen Distribution in Lower Paleozoic Slates/Phyllites of the Meguma Supergroup, Nova Scotia, Canada: Implications for

MacDonald, D. R., MacDonald, B. L. and Saunders, J. S. 2004: Geoscience Editing and Publishing; in Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, pp. 69-70.

Au and Zn-Pb Mineralization and Exploration, by U. A. Glasmacher, M. Zentilli and R. J. Ryan, 2003; *in* Chemical Geology, v. 194, p. 297-329.

CS ME 2003-2 The Touquoy Zone Deposit: an Example of "Unusual" Orogenic Gold Mineralization in the Meguma Terrane, Nova Scotia, Canada, by F. P. Bierlein and P. K. Smith; *in* Canadian Journal of Earth Sciences, v. 40, no. 3, p. 447-466.

CS ME 2003-3 Significance of U-Pb Detrial Zircon Ages in Quartzite from peri-Gondwanan Terranes, New Brunswick and Nova Scotia, Canada, by S. M. Barr, D. W. Davis, S. Kamo and C. E. White; *in* Precambrian Research, v. 126, p. 123-145.

CS ME 2003-4 $^{40}Ar^{39}Ar$ Age of the Jurassic North Mountain Basalt, Southwestern Nova Scotia, by D. J. Kontak and D. A. Archibald; *in* Atlantic Geology, v. 39, p. 47-53.

Newsletter

Nova Scotia Minerals Update, volume 20, numbers 1, 2, 3 and 4.

Open File Maps

OFM ME 2000-6. Mineral Rights Disposition Map for the Province of Nova Scotia, version 7, (June 27, 2003), version 8 (June 18, 2003), version 9 (August 20, 2003), version 10 (October 6, 2003) and version 11 (November 7, 2003), compiled by B. E. Fisher and A. S. Wenning, scale 1:500 000.

OFM ME 2003-1 Surficial Geology Map of the Whycocomagh Area (NTS 11F/14), Inverness County, Nova Scotia, by R. R. Stea and M. Feetham, 2003, scale 1:50 000

OFM ME 2003-2 Airborne Magnetic Total Field Map for Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-3 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-4 Airborne Magnetic Total Field Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-5 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-6 Airborne Magnetic Total Field Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-7 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-8 Airborne Magnetic Calculated Second Vertical Derivative Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-9 Airborne Magnetic Total Field Map for Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-10 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-11 Airborne Magnetic Total Field Map for NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, sale 1:50 000.

OFM ME 2003-12 Airborne Magnetic Calculated First Vertical Derivative Map for NTS 11K/02, Baddeck Area, Nova Sotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-13 Airborne Magnetic Calculated Second Vertical Derivative Map for NTS 11K/02, Baddeck Area, Nova Sotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-14 Airborne Magnetic Total Field Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-15 Airborne Magnetic Calculated First Vertical Derivative Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-16 Airborne Magnetic Calculated Second Vertical Derivative Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-17 Bouguer Gravity Map for the Western Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-18 Residual Bouguer Gravity Map for the Western Part of NTS 11F/10, St. Peter's Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-19 Bouguer Gravity Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-20 Residual Bouguer Gravity Map for Part of NTS 11F/11, Port Hawkesbury Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-21 Bouguer Gravity Map for NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-22 Residual Bouguer Gravity Map for NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-23 Bouguer Gravity Map for the Western Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-24 Residual Bouguer Gravity Map for the Western Part of NTS 11F/15, Grand Narrows Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-25 Bouguer Gravity Map for the Western Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-26 Residual Bouguer Gravity Map for the Western Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-27 Airborne VLF-EM Total Field Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-28 Airborne VLF-EM Quadrature Map for Part of NTS 11F/14, Whycocomagh Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-29 Airborne VLF-EM Total Field Map for Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-30 Airborne VLF-EM Quadrature Map for Part of NTS 11K/02, Baddeck Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-31 Airborne VLF-EM Total Field Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-32 Airborne VLF-EM Quadrature Map for Part of NTS 11K/03, Lake Ainslie Area, Nova Scotia, by M. S. King, 2003, scale 1:50 000.

OFM ME 2003-33 Airborne Magnetic Total Field Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-34 Airborne Magnetic Calculated First Vertical Derivative Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-35 Airborne Magnetic Calculated Second Vertical Derivative Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-36 Bouguer Gravity Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-37 Residual Bouguer Gravity Map for Part of the TGI Project Area, South-central

Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-38 Airborne VLF-EM Total Field Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

OFM ME 2003-39 Airborne VLF-EM Quadrature Map for Part of the TGI Project Area, South-central Cape Breton Island, Nova Scotia, by M. S. King, 2003, scale 1:100 000.

Open File Reports

OFR ME 2003-1 Selected Economic Mineral Deposits of the Walton Belt, Hants County, Nova Scotia: A Field Trip Guide, by R. F. Mills, G. A. O'Reilly and H. V. Donohoe, Jr.

OFR ME 2003-2 Windsor Group Stratigraphy and Structure, Drill Core Orientation Field Trip 2001, by P. S. Giles and R. C. Boehner.

OFR ME 2003-3 Report on Potential Field Modelling Project, Targeted Geoscience Initiative, Guysborough, Inverness, Richmond and Victoria Counties (NTS 11F/10, 11, 14, 15, and 11K/02), south-central Cape Breton Island, Nova Scotia, by M. S. King.

OFR ME 2003-4 Report on High-resolution Airborne VLF-EM Processing and Enhancement, Targeted Geoscience Initiative, Cape Breton, Inverness, Richmond and Victoria Counties (NTS 11F/14, 11K/02 and 11K/03), south-central Cape Breton Island, Nova Scotia, by M. S. King.

OFR ME 2003-6 The Geology and Mineral Occurrences of the Antigonish - New Glasgow - Mt. Thom Region, Northern Nova Scotia (a field trip guide), by H. V. Donohoe, Jr., R. F. Mills and G. A. O'Reilly.

Outside Publication

OP ME 2003-2 Field Trip on Three Coasts: Comparing Onshore and Offshore Records of Glaciation and Sea-level Change (a field trip guide), Canadian Quaternary Association/Canadian Geomorphological Research Group CANQUA-CGRG-2003, Halifax, Nova Scotia, June 8-12, by R. R. Stea and J. Shaw, organizers, 124 p.

Reports

Report ME 2003-1 Minerals and Energy Branch Report of Activities 2002, ed. D. R. MacDonald, 263 p.

Report ME 2003-2 Mining Matters for Nova Scotia 2003: Opportunities for Economic Development, ed. D. R. MacDonald, 25 p.

Mineral Exploration Activity in Nova Scotia, 2003

P. D. McCulloch

Mineral Exploration Monitoring

Monitoring of mineral exploration activity in Nova Scotia is coordinated through the Registry of Mineral and Petroleum Titles of the Minerals Management Division by the author, who works out of the regional office in Stellarton, Pictou County. Regional Geologists of the Regional Services Branch offices in Coxheath (Don MacNeil), Truro (Donald Weir) and Bridgewater (Sandra Johnson) assist in the field monitoring of mineral exploration activity in their respective regions.

The monitoring process covers exploration activities throughout the province and consists of visits to company offices and exploration sites, liaison with industry personnel, and the review of current assessment reports and other material submitted by industry. Liaison with industry allows the department to maintain an awareness of current exploration activities throughout the province. Assistance or advice is provided as necessary, and any drill core generated by mineral exploration activity in the province is recorded as part of the monitoring process. This core may be recovered for archiving in the Drill Core Library in Stellarton when no longer required by the companies.

The Exploration Monitoring geologist is also responsible for auditing confidential assessment reports, which are submitted to support the renewal of exploration licences. In 2003, 96 assessment reports were received and audited for compliance with the Mineral Resources Regulations.

Mineral Exploration Activity in 2003

Mineral exploration in Nova Scotia during 2003 demonstrated a modest increase in the level of activity in comparison to the previous three years, with field expenditures estimated at $4.5 million compared with $3.5 million in 2000, $2.9 million in 2001 and $2.0 million in 2002 (Table 1, Fig. 1). This increase has reversed a gradual downward trend that began after 1998, when field exploration expenditures peaked at $6.7 million. Work was concentrated primarily on gold and base metals, although exploration for industrial minerals also continued to be a focus with the level of activity reflecting the increased interest in industrial mineral commodities over the past several years. In general, exploration budgets for the mineral industry were higher in 2003, and exploration activities by junior companies has also been on the increase. This increased activity is reflected in the sustained rise in gold and base metal prices over the past year.

Preliminary figures for the total number of general claims staked in 2003 show an increase of 42% over the previous year to 17,837 claims, and more than double the amount of claim staking recorded in 2001 (Table 1, Fig. 2). Preliminary figures indicate that 18,858 claims for all commodities were in effect at the end of 2003, represented by 669 general and special licences covering an area of 305 272 ha or 3 052 km^2, approximately 5.6% of the total area of the province. The amount of exploration drilling also increased significantly in comparison to the previous two years, with a preliminary estimate of 10 000 metres in 2003, compared with 3 500 metres in 2002 and 5 400 metres in 2000.

Approximately 177 companies and individuals held exploration interests (licences or options) in the province in 2003, including 4 major, 18 junior and 39 private companies (Tables 2, 3 and 4). In addition, several mining lease holders carried out exploration and development work on leases or on unclaimed ground where these commodities did not require licences (e.g. limestone, gypsum). The levels of exploration in 2003 were much higher than in 2002, when organizations actively engaged in exploration included 1 major, 10 junior and 18

McCulloch, P. D. 2004. *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 73-86.

Table 1. Details of exploration and development activity in Nova Scotia, 1994-2003.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	P2003
Total Field Exploration Expenditures ($)	1 400 000	2 843 000	5 752 000	6 700 000	5 600 000	3 800 000	3 500 000	2 900 000	2 000 000	4 500 000
Total Licences Issued (all categories)	673	698	1 127	978	711	707	606	498	551	669
Claims in Good Standing (new and reissued)										
General	13 740	15 861	33 399	25 190	11 452	14 045	10 951	8 406	12 494	17 837
Special (Order in Council)										
Salt and Potash	66	-	214	214	820	804	255	255	500	500
Coal	218	218	311	240	253	173	-	-	102	102
Geothermal	158	158	158	158	158	158	158	158	158	158
Underground Gas Storage	-	-	-	-	106	106	106	183	183	183
Tailings	146	146	146	146	-	-	-	-	-	-
Other (gold, base metals)	255	130	130	130	130	132	10	10	10	78
Uranium*	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)
Total (excluding closures and uranium licences)	14 583	16 513	34 358	26 078	12 219	15 418	11 480	9 012	13 447	18 858
Total Area Held Under Licence										
(ha)	236 069	267 312	556 186	422 150	209 132	249 586	185 838	145 886	217 679	305 272
(acres)	583 320	660 520	1 374 320	1 043 120	516 760	616 720	459 200	360 480	537 880	754 320
Work Reported for Licence Renewals ($)	1 694 368	1 601 639	2 376 023	3 146 899	5 385 194	2 969 047	1 136 304	2 811 393	1 457 012	1 197 208
Number of Assessment Reports Received	84	111	108	133	134	100	85	72	102	96

[P]Preliminary figures for 2003

*Parentheses around uranium claims indicate ground alienation due to the uranium moratorium

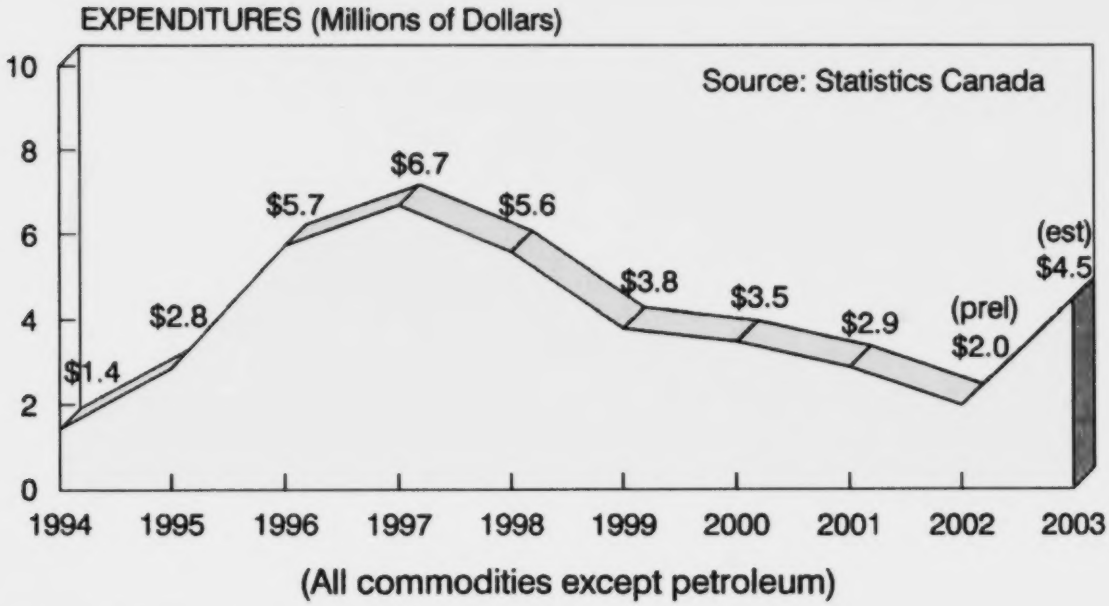

Figure 1. Exploration expenditures in Nova Scotia, 1994-2003.

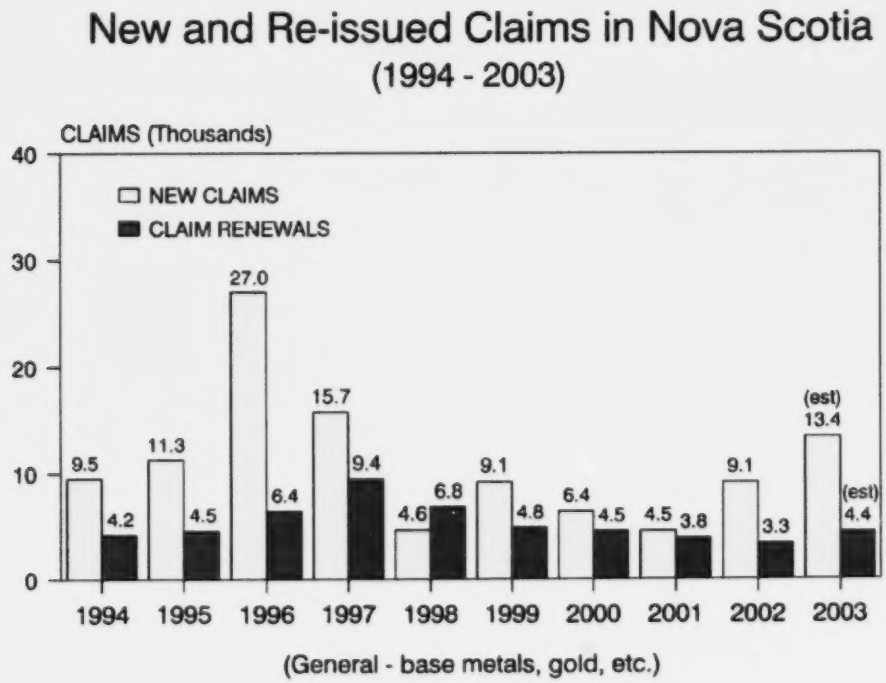

Figure 2. Claim staking in Nova Scotia, 1994-2003.

Table 2. Major companies with exploration interests (licences or options) in Nova Scotia.

	2001	2002	2003
Aur Resources Incorporated		-	-
Georgia-Pacific Canada Incorporated			-
Intragaz Limited Partnership	x	x	x
Lafarge Canada Incorporated	x	-	
Pasminco Resources Canada Company (formerly Savage Resources Canada Limited)	x	-	
Statia Terminals Canada Limited	x	-	-
W. M. C. International Limited	-		

x indicates work performed
- company inactive
blanks indicate that the company did not hold an exploration licence in that particular year

private companies (Fig. 3, Table 5), as well as a number of individuals.

Exploration Activities

Gold

Exploration for gold increased significantly in comparison to the level of activity demonstrated over the previous three years. The lower Paleozoic Meguma Group of southern mainland Nova Scotia continued to be the principal focus for gold exploration, with the majority of exploration work undertaken in Halifax and Guysborough counties. A steady increase in the price of gold over the past two years, and a more favourable investment climate for junior mining companies, have contributed to a renewed interest in the exploration and development of Meguma-hosted gold deposits.

Azure Resources Corporation continued a detailed evaluation of the Mooseland gold property in Halifax County during 2003. The company optioned the property from Globex Mining Enterprises Incorporated in September 2002, and completed surface diamond-drilling and a preliminary underground bulk sampling program on the property in 2003. In June 2003, Azure also entered into an option agreement with Newfoundland Goldbar Resources Incorporated for the Dufferin Mine property. Azure initiated a rehabilitation of the Dufferin Mine mill facilities and completed the construction of an assay lab on the property to process underground samples from both the Mooseland and Dufferin Mine properties. Under an option agreement with Meguma Resource Enterprises Incorporated, the company also completed a trenching and rock sampling program on the Miller Lake gold property in Guysborough County.

Diamond Ventures NL, under an option agreement with Moose River Resources Incorporated, completed a diamond-drilling program on the Moose River gold property to evaluate the potential for additional gold reserves along the strike extension of the Touquoy deposit. The company recently acquired additional ground to the northeast of the Touquoy deposit and plans to carry out additional drilling in 2004.

Scorpio Mining Corporation entered into an option agreement to evaluate the Cochrane Hill gold property in Guysborough County. The company initiated a detailed evaluation of previous work on the property and completed geological mapping, prospecting and rock sampling during the year. Strikezone Minerals (Canada) Limited, under an option agreement with Ellsin Resources

Table 3. Junior companies with exploration interests (licences or options) in Nova Scotia.

	2001	2002	2003
Acadian Gold Corporation			x
Avalon Ventures Limited			x
Aurogin Resources Limited		x	x
Azure Resources Corporation			x
Black Bull Resources Incorporated	x	x	x
C_2C Mining Corporation	x	-	
Corner Bay Silver Incorporated (formerly Corner Bay Minerals Incorporated)	-	-	-
Diamond Ventures NL			x
Emerald Isle Resources Incorporated	-	x	
Exploration Orex Incorporated	-	-	-
Gammon Lake Resources Incorporated	-	-	
Globex Mining Enterprises Incorporated	-	x	-
Heartland Resources Limited	-	-	-
Landis Mining Corporation			x
Monster Copper Resources Incorporated			x
Newfoundland Goldbar Resources Incorporated		-	-
Pan East Petroleum Corporation (formerly Pan East Resources Incorporated)	-	-	-
Regal Goldfields Limited	-	-	-
RJZ Mining Incorporated	-	x	-
Scorpio Mining Corporation			x
Titanium Corporation Incorporated (formerly Titanium Corporation of Canada Ltd)	x	x	x

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration license in that particular year

Incorporated, continued work on the Lake Charlotte gold property during the year. The company completed additional soil sampling, and a diamond-drilling program was undertaken on the property during the fall.

AYARCO Gold Corporation Limited continued work on the Kemptville gold property in Yarmouth County following a preliminary evaluation of the property in 2002. The company completed soil geochemical sampling, trenching and a two phase diamond-drilling program on the property during the year. Nycon Resources Incorporated continued an exploration program along the southern extension of the Salmon River anticline on the company's Muskrat Lake property in Halifax County. The company completed additional prospecting and soil geochemical sampling on the property in 2003.

Acadian Gold Corporation acquired the mineral rights, including an option agreement on ground optioned from Mr. Henry Schenkels, for the Forest Hill gold property in 2002. The company completed a detailed compilation and technical review of the deposit in 2002, and began an extensive diamond-drilling program on the property in mid-2003. The company also completed geochemical and geophysical compilation work on three additional gold exploration properties in Halifax and Guysborough counties, including the Mile Lake, Ragged Falls, and Killag Mines areas.

Table 4. Private exploration companies in Nova Scotia.

	2001	2002	2003
AYARCO Gold Corporation Limited			x
166881 Canada Incorporated	-	-	
3779751 Canada Incorporated	-	x	
Alva Construction Limited		-	x
Annapolis Valley Goldfields Incorporated			x
Atlantic Industrial Minerals Limited	-		
Asedex Minerals Corporation Limited	x	-	-
Aurion Minerals Limited	-	-	
Blackfly Exploration & Mining			-
Benrock Limited			-
Burnt Point Resources Incorporated	-	-	x
Candor Ventures Corporation		x	x
Cannova Goldfields Incorporated	-	-	
Cape Minerals Limited	-		
Celtic Clays			-
Champlain Resources Incorporated	-	x	
Cobequid Life Sciences Limited	-		
Conrad Brothers Limited	-	x	
Datum Quest Explorations		-	
Dufferin Resources Incorporated	x	-	x
Earth Search Sciences, Incorporated	-		
Ellsin Resources Incorporated	x	x	x
Elmsdale Landscaping Limited	-	-	
Erdene Gold Incorporated			x
Gallant Aggregates Limited	-	-	-
Geosearch	-	-	-
Geostorage Associates	x	x	x
Glencoe Resources Incorporated	-	x	x
Gold 'n' Crystal Minerals	-	x	-
Golden Ace Mineral Explorations Limited	-	-	-
Goliath Copperfields Limited	-		
H & E Mullen Investments Limited	-	-	x
Hansone Limited	x	x	x
Highland Range Minerals Limited	-	-	-
Huntington Explorations Incorporated	-	-	-
John Logan Enterprises Limited	-	-	-
Jubilee Minerals	-	x	-
KaoClay Resources Incorporated	-	-	-
Kelly Rock Limited		-	-
Lynx Minerals Corporation	-	-	x
MacLeod Resources Limited	x	x	x
Maritime Mica Incorporated	-	-	-

Table 4. Private exploration companies in Nova Scotia (cont'd).

	2001	2002	2003
Meguma Resource Enterprises Incorporated		x	x
Minas Basin Pulp & Paper Company Limited	-	-	-
Mineral City Enterprises Incorporated	-		
Mount Cameron Minerals Incorporated	-	-	-
North Cape Breton Resources Limited	-		
Nycon Resources Incorporated	-	x	x
Oceanview Minerals Limited	-	-	
Ochter Holdings Limited			-
Prodigy Resources Incorporated	-		
Rainbow Resources Limited	-	-	-
Robert Stewart-Patterson & Associates	-	-	
The Shaw Group Limited (formerly L. E. Shaw Limited)	x	-	-
Tri-Explorations Limited			-
True Metallic Explorations	x	-	-
Votix Corporation Limited	-	-	x
Yava Technologies Incorporated			x

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration license in that particular year

Votix Corporation Limited recently acquired several gold exploration properties in Halifax and Guysborough counties, including the Beaver Dam, Mooseland, Moser Lake, Fifteen Mile Stream, Goldenville and Cochrane Hill areas. The company completed geochemical and geophysical compilation work on the properties during the year. Hudgtec Consulting Limited completed a detailed evaluation of a large northwest-trending fault zone in the Stewart Lake area south of Forest Hill, Guysborough County. The company completed a comprehensive analysis of previous geochemical work in the area and carried out reconnaissance till geochemical sampling during the year.

Burnt Point Resources Incorporated carried out prospecting and rock geochemical sampling in the French Road-Oceanview area in southeastern Cape Breton County for gold and silver. The area is host to numerous mineral occurrences, including Cu-Zn-Co-Bi mineralization in skarn, and porphyry-related Cu-Mo-Bi-Ag mineralization.

A number of small exploration programs were also completed on several properties throughout the Meguma Group by individuals and private interests. Scott Grant carried out rock sampling and analytical work on the Harrigan Cove gold property in Halifax County, and Robert MacDonald completed a geochemical and geophysical compilation of previous work on the Gold Lake gold property in Halifax County. Avard Hudgins carried out rock sampling and reconnaissance till sampling on the Oldham gold property, and

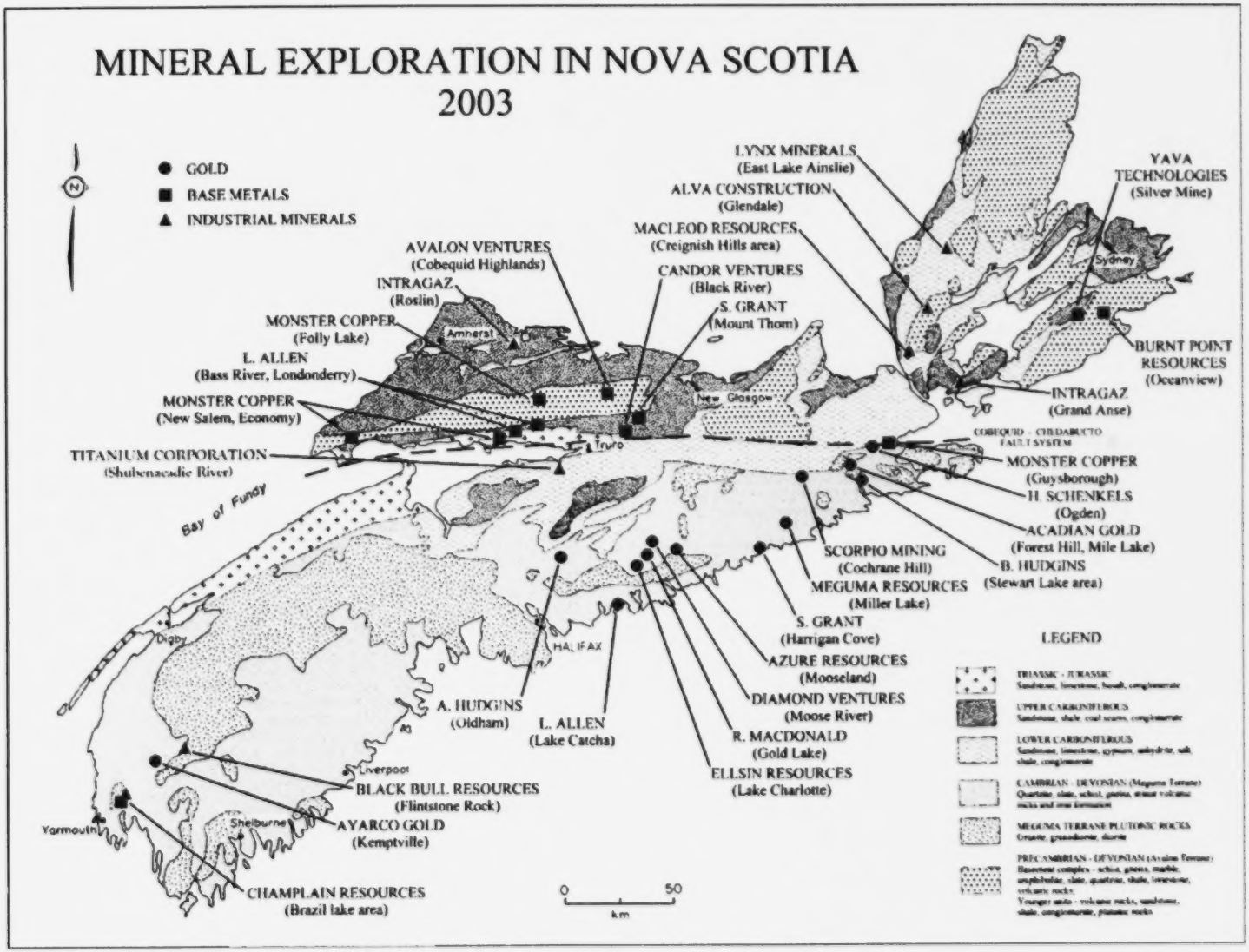

Figure 3. Mineral exploration programs in Nova Scotia, 2003.

Lindsay Allen carried out trenching and rock sampling on the Lake Catcha property in Halifax County. Henry Schenkels continued work on a gold prospect in the Susies Lake area, Guysborough County, including trenching and rock sampling.

Base Metals

Exploration for base metals showed a moderate increase in the level of activity over the previous three years. The increase in activity in 2003 was reflected primarily in a shift in focus to new geological environments associated with the potential for the discovery of Olympic Dam style iron oxide-copper-gold (IOCG) deposits along the Cobequid-Chedabucto Fault Zone in central mainland Nova Scotia. Numerous Cu-Fe occurrences, with other mineral associations including cobalt and precious metals, occur along this major structural zone. Other exploration work focused on areas of known mineral occurrences in the Carboniferous sediments of the Windsor Group in central mainland Nova Scotia and southeastern Cape Breton Island.

OntZinc Corporation, through the company's wholly owned subsidiary ScoZinc Limited, continued exploration in the Gays River area north of Halifax to evaluate the potential for additional Pb-Zn reserves in Lower Carboniferous sediments of the Windsor Group in the immediate vicinity of the Gays River Pb-Zn deposit. Work in the area included a compilation of previous work and diamond-drilling.

Monster Copper Resources Incorporated continued a detailed exploration program to evaluate the base metal and precious metal potential of several properties along the Cobequid-Chedabucto Fault Zone in central mainland Nova Scotia. The company, along with exploration partner Wallbridge Mining Company, began work on the project in 2002 to evaluate the potential for iron oxide-copper-gold (IOCG) deposits in iron-rich breccias. The company carried out geological studies, ground geophysical surveys, prospecting, and rock geochemical sampling on several properties in 2003, including the New Salem area in Cumberland County, the Economy and Folly Lake areas in Colchester County, the Lansdowne area in Pictou County, the Copper Lake area in Antigonish County, and the North Ogden area in Guysborough County.

Cobequid Gold Corporation, under an option agreement with Avalon Ventures Limited, carried out a preliminary exploration program to evaluate the potential for gold and base metals in Silurian and Devonian volcanic and intrusive rocks in the eastern Cobequid Highlands area north of the town of Truro in Colchester County. Initial work on the property included prospecting, geological mapping and stream sediment geochemical sampling. Avalon Ventures Limited entered into an option agreement in 2003 to evaluate the potential for iron oxide-copper-gold (IOCG) deposits in the Mount Thom area northeast of the town of Truro bordering Pictou and Colchester Counties. The project area includes the Mount Thom Cu-Co-Au prospect. Preliminary work on the property included prospecting and rock geochemical sampling.

Candor Ventures Corporation continued work in the Black River area near Riversdale, Colchester County, to evaluate the iron oxide-copper-gold potential in the area of a known copper showing along the Cobequid-Chedabucto Fault Zone. Work on the property included prospecting, geological mapping and soil sampling. Elk Explorations Limited carried out prospecting and rock geochemical sampling for gold and base metals in the immediate vicinity of the Bass River magnetite prospect north of Bass River, and in the Londonderry area, Colchester County.

Yava Technologies Incorporated completed a diamond-drilling program during the fall on the former Yava lead deposit located near Silver Mine in Cape Breton County. The property hosts a 4.5 million ton stratabound lead deposit in Carboniferous sandstones grading 2.79% lead with minor zinc. The company is currently evaluating the feasibility of using low-cost extraction methods for the lead ore.

Industrial Minerals

Exploration for industrial minerals continued at approximately the same level as the previous three

Table 5. Mineral exploration programs in Nova Scotia, 2003.

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
L. Allen	Lake Catcha, Halifax County	Gold	Trenching, rock sampling
Acadian Gold Corporation	Forest Hill, Guysborough County	Gold	Compilation work, diamond-drilling
Alva Construction Limited	Glendale area, Inverness County Churchview area, Inverness County	Carbonates (marble)	Trenching, rock sampling, diamond-drilling Test pitting
A. Hudgins	Oldham, Halifax County	Gold	Rock and till sampling
Avalon Ventures Limited	Mount Thom area, Colchester County	Base metals, gold	Prospecting, rock sampling
AYARCO Gold Corporation	Kemptville, Yarmouth County	Gold	Soil sampling, trenching, diamond-drilling
Azure Resources Corporation	Mooseland, Halifax County	Gold	Diamond-drilling, underground bulk sampling
Burnt Point Resources Incorporated	French Road area, Cape Breton County	Gold, silver	Prospecting, rock sampling
Candor Ventures Corporation	Black River area, Colchester County	Base metals, gold	Geological mapping, prospecting, soil sampling
Champlain Resources Incorporated	Brazil Lake area, Yarmouth County	Industrial mineral commodities	Mineral processing studies, diamond-drilling
Cobequid Gold Corporation	North-central mainland Nova Scotia	Base metals, gold	Geological mapping, prospecting, silt sampling
Diamond Ventures NL	Moose River, Halifax County	Gold	Diamond-drilling
Elk Exploration Limited	Bass River area, Colchester County Londonderry area, Colchester County	Base metals, gold	Prospecting, rock sampling
Glencoe Resources Incorporated	Upper Glendale area, Inverness County	Carbonates (marble)	Trenching, rock sampling
Hudgtec Consulting Limited	Stewart Lake area, Guysborough County	Gold	Compilation work, till sampling
H. Schenkels	Susies Lake area, Guysborough County	Gold	Trenching, rock sampling
Intragaz Energy Limited Partnership	Roslin area, Cumberland County Grande Anse area, Richmond County	Salt (underground storage)	Compilation work
Landis Mining Corporation	Shubenacadie area, Colchester County	Mineral sands (titanium)	Sand sampling
Lynx Minerals Incorporated	Trout Brook area, Inverness County	Barite	Trenching, diamond-drilling
M. Cullen	Staples Brook, Colchester County Kemptown, Colchester County	Coal	Diamond-drilling
MacLeod Resources Limited	Creignish area, Inverness County	Carbonates (marble)	Geological mapping, trenching, rock sampling
Meguma Resource Enterprise Inc.	Miller Lake, Guysborough County	Gold	Trenching, rock sampling
Monster Copper Resources Incorporated	Central mainland Nova Scotia	Base metals, gold	Geological studies, prospecting, ground geophysics

Table 5. Mineral exploration programs in Nova Scotia, 2003 (cont'd)

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
Nycon Resources Incorporated	Muskrat Lake, Halifax County	Gold	Prospecting, soil sampling
P. MacKinnon	Glendale area, Inverness County	Graphite	Rock sampling
ScoZinc Corporation	Gays River, Halifax County	Base metals	Compilation work, diamond-drilling
R. MacDonald	Gold Lake, Halifax County	Gold	Compilation work
Scorpio Mining Corporation	Cochrane Hill, Guysborough County	Gold	Geological mapping, prospecting, rock sampling
S. Grant	Harrigan Cove, Halifax County	Gold	Prospecting, rock sampling
Strikezone Minerals (Canada) Limited	Lake Charlotte, Halifax County	Gold	Soil sampling, diamond-drilling
Titanium Corporation Incorporated	Cobequid Bay area, Hants County	Minerals sands (titanium)	Drilling
Votix Corporation Limited	Beaver Dam, Halifax County	Gold	Compilation work
Yava Technologies Incorporated	Silver Mine, Cape Breton County	Lead	Diamond-drilling

years, with activity focused on commodities including titanium, marble (carbonate), barite, pegmatite minerals (mica, quartz, feldspar, spodumene), and graphite.

Titanium Corporation Incorporated continued a detailed evaluation of the titanium-bearing heavy mineral sands in the Shubenacadie River - Cobequid Bay area near Maitland, Hants County. The company completed additional drilling and sample analysis in the Cobequid Bay during the summer to evaluate part of a high-grade, titanium-bearing sandbar outlined in a previous drilling program. Landis Mining Corporation carried out a preliminary sampling program in the Shubenacadie area, Colchester County, in 2003 to evaluate the titanium-bearing heavy mineral sands along the Shubenacadie River between Fort Ellis and Pine Grove. The claim group lies immediately south of the Titanium Corporation Incorporated claim holdings.

Alva Construction Limited continued exploration activities on the Glendale carbonate deposit located approximately 4 km north of Glendale, Inverness County. Work on the property included trenching, rock sampling and diamond-drilling. The company also excavated a test pit in the Churchview area, Inverness County, in the immediate vicinity of the company's quarry operation along the Soapstone-Roseburn Road.

Glencoe Resources Incorporated completed additional work on the Upper Glencoe carbonate deposit located approximately 5 km south of Upper Glencoe, Inverness County. Work on the property included trenching and rock sampling. MacLeod Resources Limited carried out detailed work in the Creignish area, Inverness County, to evaluate the resource potential for marble occurrences identified in a reconnaissance program in 2002. Work on the property included geological mapping, trenching and rock sampling.

Perry MacKinnon completed additional work on a graphite prospect located approximately 3 km north of Glendale, Inverness County. Work on the property included a detailed examination of till that had been excavated during a trenching program completed in 2002, and analytical work on graphite samples.

Lynx Minerals Incorporated, in association with Atlantic Industrial Minerals Incorporated, continued to evaluate the potential for discovering additional barite reserves in the area immediately north of Trout Brook along the southeast side of Lake Ainslie, Inverness County. The company completed trenching and diamond-drilling on the property during 2003.

Champlain Resources Incorporated continued a detailed exploration program in the Brazil Lake area, Yarmouth County, to evaluate the Brazil Lake pegmatite occurrences for industrial mineral commodities. The company carried out mineral processing studies and diamond-drilling on the property early in 2003.

Other

Intragas Energy Limited Partnership carried out an evaluation of the potential for developing underground bulk hydrocarbon storage in the extensive salt deposits in Lower Carboniferous sediments of the Windsor Group in the Roslin area, Cumberland County, and in the Grande Anse area, Richmond County. The current work program consisted of a review of previous geological and geophysical exploration.

Exploration for coal resources was undertaken by Michael Cullen in the Staples Brook and Kemptown areas, Colchester County, during the fall of 2003. The current work program consisted of diamond-drilling on the two properties.

Assistance to Prospectors and Small Developers at the Nova Scotia Department of Natural Resources

R. F. Mills

The Nova Scotia Department of Natural Resources (DNR) is the only natural resource department in the nation to have a full-time staff geologist devoted to assisting those in the mineral exploration industry with projects in the pre-development phase, such as prospectors and small developers. Assistance consists of a variety of tasks ranging from prospector education and development, office assistance on site and at the department's office in Halifax, field assistance on site anywhere in the province, assistance in developing promotional material with exploration plans, assistance with data reduction, assessing results on mineral exploration properties, and contributing to the development of the Nova Scotian mineral exploration industry in general. Assistance and liaison with the various industry bodies, such as the Nova Scotia Chamber of Mineral Resources, the Nova Scotia Prospectors Association, the Nova Scotia Mining Society and the Nova Scotia Mineral and Gem Society, is offered to assist these groups address legislative and policy issues related to their common goals, such as access to ground for the purpose of prospecting.

Prospector education and development consists of course development, field trip development and delivery to large groups, workshops on exploration techniques and issues of importance, on-site education in small groups as well as one-on-one meetings, and field assistance on prospects and properties. Mineral exploration industry trends are considered when deliberating prospector education needs. Geological environments that meet the criteria as amenable to exploration for the commodities that conform to such trends are highlighted and promoted. This is carried out in conjunction with other promotional efforts within the Geological Services Division, such as the promotion of the current IOCG (iron oxide-copper-gold) exploration model, which is analogous to the model presented for hydrothermal vein breccia deposition in the Cobequid-Chedabucto Fault Zone (O'Reilly, 1996).

The two major field trips per year, which are planned and implemented in co-operation with the Nova Scotia Prospectors Association, have two main purposes. The field trips educate prospectors in the field as well as highlight mineral prospects for the purpose of further prospecting and subsequent development, if warranted. This has resulted in the staking of hundreds of active claims in areas where field trips have taken place within the last calendar year. Very readable field guides have been indexed and placed in the library of the Nova Scotia Department of Natural Resources as resource material for those engaged in mineral exploration, adding to the provincial database of material used for the purpose by both enthusiasts and professionals.

Further to this purpose of prospector education, DNR is developing a web-based prospecting course, with course materials that will be available to prospectors online. This will include copies of past field trip guides, so that interested parties will be able to reconstruct past field trips, as well as access to information pertaining to the many types of exploration techniques that are applicable in Nova Scotia, mining legislation, and general prospecting information and development modules.

A large component of assistance offered to prospectors consists of on-site field assistance with prospectors, delivered one-on-one or to small partnerships. This work is continuous, at many localities around the province. This also means that assistance is often offered with respect to library research, as well as the development of maps and reports for properties.

Mills, R. F. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 85-86.

One-on-one assistance has resulted in the discovery of new gold-bearing veins on properties in traditional gold districts such as Oldham, Halifax County, Whiteburne, Queens County, and North Brookfield, Queens County, as well as discovery of previously undocumented workings at North Brookfield, Queens County, and near Voglers Cove, Lunenburg County. Exploration in these traditional gold districts is not confined to activities on traditional sites within the districts either, as shown by exploration of a new lode gold target in the Goldenville, Guysborough County, vicinity, following a new exploration model developed by the mineral rights holder with the assistance of DNR or in the case of an entirely new discovery in the Ecum Secum, Guysborough County, area. Discoveries of previously unreported exploration and development in the Tangier, Halifax County, area, and the Farmington, Lunenburg County, area are also under investigation. Outside of traditional gold districts, follow-up work continues on other gold prospects, as well as prospects for the development of base metals, rare earth elements, and industrial mineral deposits in most counties of Nova Scotia.

Some issues of land use at active pits and quarries are being co-ordinated by the Geological Services Division in an effort to keep pit owners aware of issues of importance to them as well.

A natural extension of the prospecting activity involves education about prospecting in particular, and geology in general, to those in related fields of interest. To this end, the project reaches out to those scientists and activists in related fields at DNR functions involving forestry science, at international forums, such as the Canadian Quaternary Association meeting held in Halifax in August 2003, and has even found a place among members of the natural science community while attending events at park facilities run by DNR. This results in small targeted publications for these groups as well as for the (park) facilities involved.

Reference

O'Reilly, G. A. 1996: Vein and breccia deposits of Fe-Cu-Co-Ni-Ba-Au associated with the Cobequid-Chedabucto Fault Zone, Nova Scotia; Nova Scotia Department of Natural Resources, Information Circular 47.

Progress Report on a New Mapping and Resource Evaluation Program for Central Nova Scotia[1]

R. D Naylor, B. E. Fisher, P. S. Giles[2], T. A. Goodwin, D. J. Kontak and P. J. Harvey[3]

Introduction

During the summer of 2003, the Geological Survey of Canada (GSC) and the Nova Scotia Department of Natural Resources (DNR) began a two-year geological mapping and resource evaluation project in central Nova Scotia. The work forms part of the second phase of the Targeted Geoscience Initiative Program (TGI-2), a national program designed to assist and promote mineral and energy exploration. In addition to GSC and DNR staff, the Nova Scotia component of TGI-2 will include researchers from various Canadian universities, other government organizations, and industry.

The Nova Scotia TGI-2 project focuses on the area covered by NTS sheets 11E/05, 11E/06, 11E/07, 11E/08 and 11F/05 (Fig. 1). Our goal will be to combine new project data with formerly unpublished, high-quality historical data to produce maps and reports that will be of significant interest to mineral and hydrocarbon exploration companies.

The project includes five major components:
(1) mapping, (2) mineral deposit research,
(3) energy resource research, (3) seismic interpretation and reprocessing, and
(5) geophysical mapping and modelling.

Geological Mapping

The majority of the study area is underlain by Carboniferous strata that are of considerable interest for hydrocarbon and mineral resource potential. Unfortunately, uncertainty about stratigraphy and structure has often hindered exploration efforts. Higher quality bedrock maps are required to develop more refined stratigraphic and structural models to assist mineral and hydrocarbon exploration. High-quality (often 1:10 000 scale) bedrock data exist for significant parts of the study area. However, most of these data have not previously been released as maps. Digital compilation and interpretation of these data have been among the top initial priorities.

Two unpublished data sets are being used to compile new digital maps within the project area. The area covered by these mapping projects is south of the Cobequid-Chedabucto Fault Zone (CCFZ) within the St. Marys Basin (see Fig. 1). The earliest data set was collected from 1968 to 1971 as part of the St. Marys River Basin Project. This project was undertaken by the Nova Scotia Department of Mines and included geological mapping and soil geochemistry, as well as gravity, VLF and seismic surveys (see Nova Scotia Department of Mines, Annual Report on Mines 1971, p. 71-72). The original field notes and working maps are still available from this project, and they have provided excellent outcrop locations and bedding orientations. Data for the St. Marys River Basin project will be published by October 2004 as an NSDNR digital product, which may be viewed in map form using ArcView®.

The second data set was collected during 1993 and 1994 by Randy Rice and Brendan Murphy as part of the federal NATMAP program. Although some very useful publications (e.g. Murphy and Rice, 1998; Murphy, 2000) were produced by this project, the detailed mapping data have not previously been made available. The Rice and Murphy data will be published as a DNR open file map that will include all available outcrop locations and structural data. Publication of this map is planned for January 2005.

[1]Funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources under the Targeted Geoscience Initiative Project (Phase 2): Geological Mapping and Resource Evaluation in Central Nova Scotia
[2]Natural Resources Canada, Geological Survey or Canada, PO Box 1006, Dartmouth, Nova Scotia B2Y 4A2
[3]Nova Scotia Department of Energy, PO Box 2664, Halifax, Nova Scotia B3J 3P7

Naylor, R. D., Fisher, B. E., Giles, P. S., Goodwin, T. A., Kontak, D. J. and Harvey, P. J. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 87-91.

In addition to publishing previously unreleased map data, project staff are also compiling digital versions of the major published geological maps within the TGI-2 project area. These databases will be made available for free download from the DNR website as digital products.

New geological mapping will be used to fill existing outcrop data gaps and to study specific stratigraphic and structural questions. During the summer of 2003, most of the new mapping was undertaken in the Cumberland and Mabou groups adjacent to the Cobequid Highlands. This work, coupled with new palynological sampling, helped refine stratigraphic subdivisions within the Cumberland Group and to better understand the nature of some of the major boundary faults in the study area. During the 2004 field season, mapping will focus on specific areas that contain important outcrops of the Horton, Cumberland and Mabou groups. This work will include a close look at the nature of the boundary between the St. Marys and Shubenacadie basins, further study of the Carboniferous stratigraphy throughout the study area, and detailed structural analysis of major fault zones. Palynological sampling will also be undertaken to support the mapping efforts.

In addition to the map products mentioned above, two new 1:50 000 scale geological maps of NTS areas 11E/06 and 11E/07 and eight 1:10 000 scale maps of the Carboniferous strata between Londonderry and Kemptown will be released as part of this project (see Fig. 1). These maps will include the highest quality historical information that is available, and all the new mapping data collected by this project.

Mineral Deposits Research

Assessment of specific mineral deposits, and hydrocarbon potential, will also form a component of this project. Activities include study of regional thermal maturation data and Cu-Co-Au mineralization near Mount Thom.

The presence of abundant vein and disseminated Fe-oxide mineralization with associated carbonate alteration and anomalous Cu±Co±Ni±Au along and peripheral to the Cobequid-Chedabucto Fault Zone of mainland Nova Scotia has recently generated interest because of analogies with the IOCG (iron oxide-copper-gold) environment. In order to assess the validity and applicability of the various models proposed for IOCG mineralization globally, several aspects of the mineralizing environments and geological setting of the area of interest have to be addressed. Foremost among these concerns are the nature of mineralization, associated elemental enrichment (e.g., Co, Ni, Au, REE, Mo, Zn, etc.), mineral paragenesis, and absolute age of mineralization. The nature of mineralization in IOCG deposits is highly variable and can vary within a mineralized zone. Thus, documentation of the nature of mineralization and elemental enrichment is mandatory. The project will also address the age and nature of magmatism within and peripheral to the fault, and how these compare to magmatism in the nearby Cobequid and Antigonish highlands regions. The role and type of magmatism in IOCG deposits is debated, but its occurrence in close association with several such deposits demands that this issue be addressed. The project will study the extent and nature of alteration associated with the mineralized centres. Widespread alteration forms an integral part of the IOCG model and, therefore, it is crucial to fully characterize its chemical and geometrical aspects. A particular fluid chemistry is peculiar to IOCG deposits. Thus, characterizing the fluids associated with mineralization and alteration is an important aspect of the IOCG model. This component of the deposit environment will be assessed via fluid inclusion studies and stable isotopic analysis.

In order to address these issues a suite of samples from archived material collected from within the TGI-2 study area over the past several years has been prepared for initial study. The samples are keyed to mineralization in the Londonderry, Mount Thom and Copper Lake areas, and some lesser mineralized areas with aspects of IOCG mineralization (e.g. specular hematite). Representative samples have been prepared for petrographic and mineralogical examination, fluid inclusion study, stable isotopic analysis, and to determine the age of both the mineralization (Mount Thom, Copper Lake) and related igneous rock. Results of these initial sample sets will help

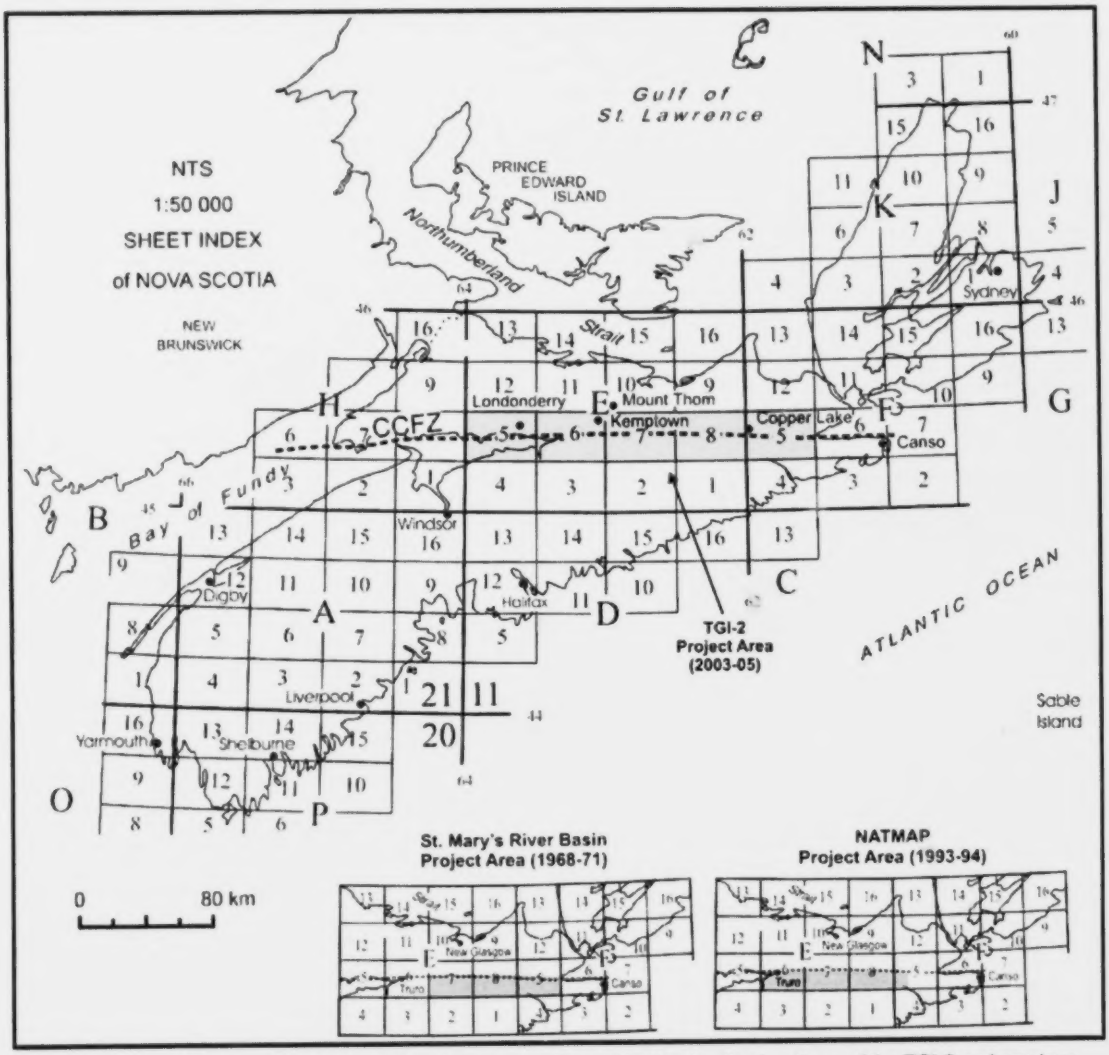

Figure 1. National Topographic System (NTS) index map of Nova Scotia showing locations of the TGI-2 and previous project areas. CCFZ = Cobequid-Chedabucto Fault Zone.

in determining the further detailed work required to address the features that are critical to assessing the validity of the IOCG model for this part of mainland Nova Scotia.

A limited, regional geochemical sampling program totalling approximately 100 sample sites is planned for the 2004 field season. Humus, soil and till samples will be collected at each sample site along three or four north-south (roadside) traverses across NTS map areas 11E/06, 11E/07 and 11E/08, plus along one east-west traverse line parallel to Trans Canada Highway 104. Geochemical results for humus, soil and till samples help characterize the regional geochemical signature of the Cobequid-Chedabucto Fault Zone for the various sample media, and further assist current exploration efforts for IOCG mineralization in the area. Strict quality assurance/quality control protocols will be followed for all phases of sample collection, preparation and analysis.

Energy Resource Research

The study area has attracted interest for both coal and hydrocarbon exploration. Industry exploration is underway for near-surface coal and large areas are currently under licence for petroleum exploration.

During the 2003 field season we studied the regional stratigraphy of coal-bearing units within the project area. Mapping, new palynological analyses, and recent industry seismic data were used to develop a better understanding of the coal-bearing strata. Our work suggests that there are at least two significant coal-bearing units, separated by hundreds of metres of non-coal-bearing strata. Coal within these units is locally of high quality. However, the lateral extent of individual coal seams is often affected by structural features and/or rapid lateral changes in coal quality. During 2004 we will undertake detailed stratigraphic and structural modelling of specific coal-bearing intervals to more closely examine local variation in seam thickness and quality.

Evaluation of hydrocarbon potential in the project area will largely be based on analysis of recent industry seismic data. However, we will include some work on characterization of source rocks and a regional maturation study. During 2004 we will compile existing maturation and source rock data for the entire project area. Additional sampling and testing will occur if more data are required.

Seismic Interpretation and Reprocessing

During 2003 we compiled the location of all known seismic surveys within the project area. This information will be released as a digital product for free download through the DNR website and will include locations of all the shot points for each survey. Steep bedding dips and complex faults make survey design and processing difficult in the study area. However, some of the more recent surveys have realized some very good results. Although the most recent industry seismic data are still proprietary we were able to obtain permission to work with a consultant to interpret a number of useful lines in the northeastern corner of NTS area 11E/06. This information is being used in concert with mapping data to produce a series of cross-sections that extend from the Cobequid Fault to the northern edge of the St. Marys Basin.

During 2004 we plan to reprocess a number of seismic lines and work with industry to gain access to additional recent seismic data. Whenever possible, interpreted seismic cross-sections will be made available for free download.

Geophysical Mapping and Modelling

A variety of airborne geophysical data are available for the project area. Aeromagnetic and gravity coverage exists for the entire area, while VLF-EM surveys provide more local coverage. In 2003, Steve King was contracted to prepare geophysical maps for the entire project, including the following:

- Aeromagnetic (total field, calculated first and second vertical derivative)
- Bouguer gravity
- Residual Bouguer gravity
- VLF-EM line and ortho total field (local coverage only).

These maps will be made available as digital images for free download during the summer of 2004. They will also eventually be available as open file maps in a PDF format.

During 2004 we will be evaluating sites as potential candidates for detailed geophysical modelling. We are also hoping to integrate new (2004) industry airborne geophysical surveys into our geophysical coverage.

Summary

TGI-2 is providing the opportunity to undertake important research on one of the most interesting areas for mineral and energy exploration in the province. The multi-faceted approach incorporated into the project design will ensure the information generated will be of interest to a broad spectrum of

clients. Compilation and release of previously unpublished historical data, coupled with new work, will make available a large volume of data despite the relatively short duration of the project. Project results will be made available as open file maps, online digital products, reports in the annual Mineral Resources Branch Report of Activities, and journal publications. Presentations on project results will also be given at the Mining Matters for Nova Scotia conference and the Atlantic Geoscience Society meeting. Two field trips will also be run that will be open to anyone.

Mineral Inventory Project Activities for 2003

G. A. O'Reilly and G. J. DeMont

Introduction

During 2003, Mineral Inventory staff were involved in several initiatives throughout the province (Fig. 1). Many of these activities were directly related to, and a continuation of, planned activities from the immediately preceding years. Others were related to initiatives outside of originally planned project activities. George O'Reilly worked on Mineral Inventory Project tasks on the mainland, while Garth DeMont worked on Cape Breton Island.

Field Activities

Field activities on the mainland (O'Reilly) focused on the potential for iron oxide-copper-gold deposits (IOCG) associated with the regional scale, Cobequid-Chedabucto Fault Zone (CCFZ; Fig. 1). The geological relations of mafic and felsic intrusions with their enclosing lower and middle Carboniferous sedimentary country rocks was of particular interest. A small intrusion of granite within Mabou Group rocks at Mount Thom, Colchester County, and gabbroic and granitic dykes

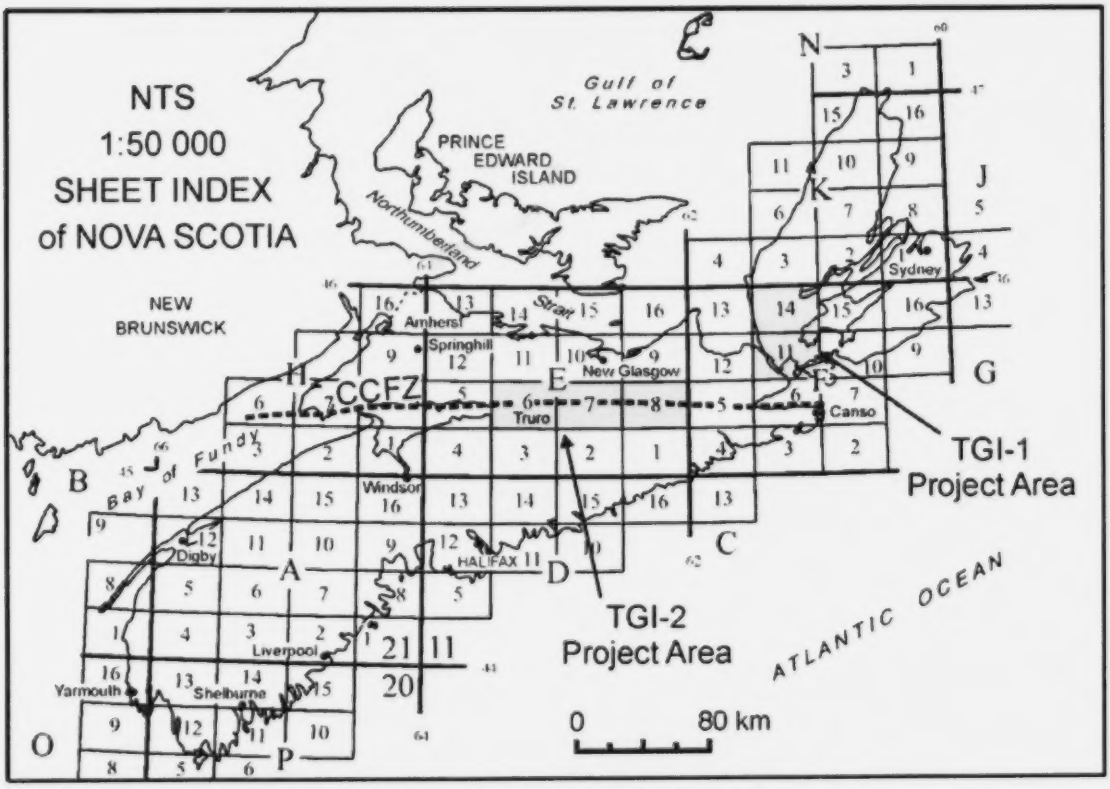

Figure 1. NTS map index of Nova Scotia, showing features discussed in this report.

O'Reilly, G. A. and DeMont, G. J. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 93-95.

and small plutons in the Lorne, Pictou County, within Mabou and Horton group rocks were examined. These investigations are considered preliminary and an initiation of mapping related to phase two of the joint federal - provincial Targeted Geoscience Initiative (TGI-2; Fig. 1). The investigations will continue through 2004 on NTS map areas 11E/06, 07 and 08 (Fig. 1). For more information on the Targeted Geoscience Initiative, see Naylor *et al.*, this volume.

Another area of interest is the geology of small, fault-bounded wedges of carbonate rocks that occur adjacent to, and within, some of the major fault splays of the CCFZ. Usually, past mapping assigned these carbonate enclaves to the Carboniferous Windsor Group marine sequence; however, evidence now suggests that at least some may have another origin. Some may have been formed by carbonate-rich hydrothermal fluids upwelling along the CCFZ, while others may actually be Triassic calcrete deposits.

Field activities on Cape Breton Island (DeMont) were mostly limited to an examination of the economic potential of Precambrian carbonate units in the Creignish Hills and North Mountain areas. This was a joint effort between DeMont (DNR), Nova Scotia Department of Economic Development, Strait Highlands Regional Development Agency, and Enterprise Cape Breton. DeMont's contribution was geological expertise, while the other organizations provided funds for trenching and sampling. This examination is a spin-off stemming from encouraging results from the recently completed federal - provincial Targeted Geoscience Initiative Phase 1 (TGI-1; Fig. 1), which showed a promising potential for high-calcium lime units within the highland blocks of south-central Cape Breton (NTS 11F/11 and 11F/14). High quality lime is used for applications like stack-scrubbers, agriculture lime, flux in steel making, and in the paper industry. Sources of this commodity are actively being sought by Glencoe Resources and ALVA Construction Limited.

Native gold in stream sediments in the watersheds of the south and western side of Whycocomagh Mountain have been known for many years. Although long known, and the focus of several exploration efforts, some of which involved trenching and construction of an adit, it is felt that the source of the gold anomalies has never been explained. DeMont carried out a preliminary gold panning assessment along some of the stream courses during 2003. This work returned encouraging results, with native gold being found in samples over a wide area, such that a more detailed and systematic evaluation is planned for 2004.

Office Activities

Version 7 of the Mineral Occurrence Database

The Mineral Inventory Project released Version 7 of the Mineral Occurrence Database in the spring of 2003. This data release is considered substantial, as it includes the final results of a mineral occurrence research compilation and field examinations for the TGI-1 study area (NTS map areas 11F/11, 11F/14). The update includes information for both metallic and industrial mineral occurrences. In addition, Version 7 includes updated information for several mineral occurrences in the Eastern Shore region of the mainland. These include records for the past-producing Fifteen Mile Stream and Lake Charlotte gold districts, and the currently producing Brookfield barite deposit and past-producing Brookfield iron mines.

West Paradise Diamond-drill Core Review

The Department of Natural Resources currently maintains a drill core storage facility in West Paradise, Annapolis County. During 2003, the department decided to relinquish ownership of this facility. This required an assessment of the materials stored there and decisions as to what will be retained and transported to the department's Stellarton Core Library. The Paradise facility contains diamond-drill core and samples from a variety of exploration efforts carried out in southwest Nova Scotia over the years. O'Reilly agreed to examine the drill core from past projects of Falconbridge Limited. This task was carried out

over the field season and representative drill cores and drill profiles were selected for several of the projects. These materials will be moved to Stellarton and included in the departmental collection.

Special Water Advisory Group (SWAG)

The departments of Education, and Transportation and Public Works carried out a full environmental review of Sir John A. MacDonald High School near Hubley (west of Halifax) in the spring of 2002 in response to some health concerns that arose among the students there. The review revealed that the school's drilled well water contained levels of radioactive lead (Pb^{210}) that exceeded the Canadian Guidelines for Drinking Water Quality guideline of 0.1 Bq/l. In response, the Department of Environment and Labour assembled a Special Water Working Group (SWAG) to assess the extent of the problem. SWAG consists of representatives from the provincial departments of Environment and Labour, Education, Transportation and Public Works, Health, and Natural Resources. As well, SWAG has a representative from Health and Welfare Canada. G. A. O'Reilly from the Mineral Inventory Project serves as the Natural Resources representative on SWAG and provides expertise on geological factors that relate to the occurrence of uranium and its related radiogenic daughters, of which Pb^{210} is one. The mandate of SWAG is to assess the extent of the problem and make recommendations to government through the Department of Environment and Labour on appropriate action and treatment options.

It has been known for 25-30 years that groundwater in several geological terrains of the province frequently contain elevated levels of naturally occurring radionuclides, such as uranium and radon. Pb^{210}, a uranium decay series daughter, is related to this phenomenon. A sampling program by SWAG quickly determined that the elevated Pb^{210} problem is not limited to Sir John A. MacDonald school and occurs in other regions of the province, but most notably within the corridor between Halifax and New Ross that is underlain by granitic rocks of the South Mountain Batholith. To date, all the 185 schools of the province that obtain their drinking water from drilled or dug wells have been tested. From these it has been determined that 18 schools have drinking water that exceeds the allowable level for U, Pb^{210} or both. SWAG is currently assessing treatment options and carrying out additional sampling to further assess the extent of the phenomena.

Formal Presentations and Field Trips

Staff of the Mineral Inventory Project were involved in several formal oral presentations and field trips throughout the year. G. J. DeMont prepared and presented a talk titled "Why All the Excitement About Carbonate Rocks" at the Mineral Resources Branch Mining Matters conference in November 2003. The talk summarized some of DeMont's activities related to TGI-1. G. A. O'Reilly co-authored a presentation with D. J. Kontak titled "Non-Meguma Gold Mineralization Environments in Nova Scotia" which was presented by Kontak at the Mining Matters conference. The talk summarized the features of many of the gold-mineralized environments in the province, other than the more widely known mesothermal, lode gold deposits that occur within the metasedimentary Meguma Group.

G. A. O'Reilly, along with H. V. Donohoe and R. F. Mills, prepared and lead two field trips for the Nova Scotia Prospectors Association. A spring trip visited several sites in the Walton Belt of Hants County. This included visits to places like the Walton barite-base metal deposit, Tennycape manganese mine and the Shubenacidie River titanium sands. A fall trip to the Antigonish Highlands and Mt. Thom area visited several sites of geological interest along the Northumberland Shore, the Cross Roads Ohio Cu-Pb-Zn deposit, Stellarton Coal Mine, and Mt. Thom Cu-Co-Au prospect.

Age and Petrochemistry of Mafic Sills in Rocks of the Northwestern Margin of the Meguma Terrane, Bear River - Yarmouth Area of Southwestern Nova Scotia

C. E. White and S. M. Barr[1]

Introduction

The Cambrian to Early Devonian Goldenville, Halifax, White Rock and Torbrook formations, exposed along the northwestern margin of the Meguma Terrane in southwestern Nova Scotia, are characterized by the presence of abundant mafic sills (Loring, 1954; Taylor, 1969; Smitheringale, 1973; Doyle, 1979; Trapasso, 1979; White *et al.*, 1999). Sills are particularly abundant in the Halifax, White Rock and Torbrook formations in the Wolfville-Kentville, Nictaux-Torbrook and Bear River areas (Fig. 1), and are so abundant in places that they could be termed swarms. Recent fieldwork related to the Southwest Nova Scotia Mapping Project in the Bear River to Yarmouth area has documented the presence of additional mafic sills not shown on previous maps, and some of these sills are located well down in the stratigraphy of the Goldenville Formation.

The purpose of this paper is to provide information about the field relations, age, and petrochemistry of sills in the area between Bear River and Yarmouth. The data are used to characterize and compare these sills, and to interpret their chemical affinity and tectonic setting through an emplacement history that appears to have extended from Early Cambrian to Middle Devonian.

Geological Setting

Stratigraphic units in the map area include the Cambrian to Ordovician Meguma Group, (consisting of the Goldenville Formation and overlying Halifax Formation), the Silurian White Rock Formation and the Early Devonian Torbrook Formation (Figs. 1, 2, 3).

The Goldenville Formation consists of grey medium- to thick-bedded metasandstone, locally interlayered with green, cleaved metasiltstone and rare black slate (Horne *et al.*, 2000; White *et al.*, 2001). A distinctive feature of the Goldenville Formation near High Head (Figs. 1, 3) is a <1 km thick interval of mainly grey-green (High Head member) metasiltstone that contains abundant trace fossils. The Early Cambrian deep-water ichnofossil *Oldhamia* was observed within this unit, which suggests that the lower part of the Goldenville Formation (below this interval) may extend into the Neoproterozoic.

The Halifax Formation in the map area has been subdivided into three stratigraphic units named, from oldest to youngest, the Bloomfield, Acacia Brook/Cunard and Bear River/Sissiboo River members (White *et al.*, 1999, 2001; Horne *et al.*, 2000). The Bloomfield member consists of distinctly banded maroon and green, thinly bedded metasiltstone and slate. Conformably overlying the Bloomfield member is black to rust-brown slate with minor metasandstone layers of the Acacia Brook/Cunard member. The Bear River/Sissiboo River member is interpreted to conformably overlie the Acacia Brook/Cunard member and consists of silty slate with minor metasandstone and slate. Early Tremadoc acritarch microfossils were reported by Doyle (1979) from the Halifax Formation exposed along Bear River near the contact with the White Rock Formation. Specimens of the graptolite *Rhabdinopora flabelliforme*, an

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White, C. E. and Barr, S. M. 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 97-117

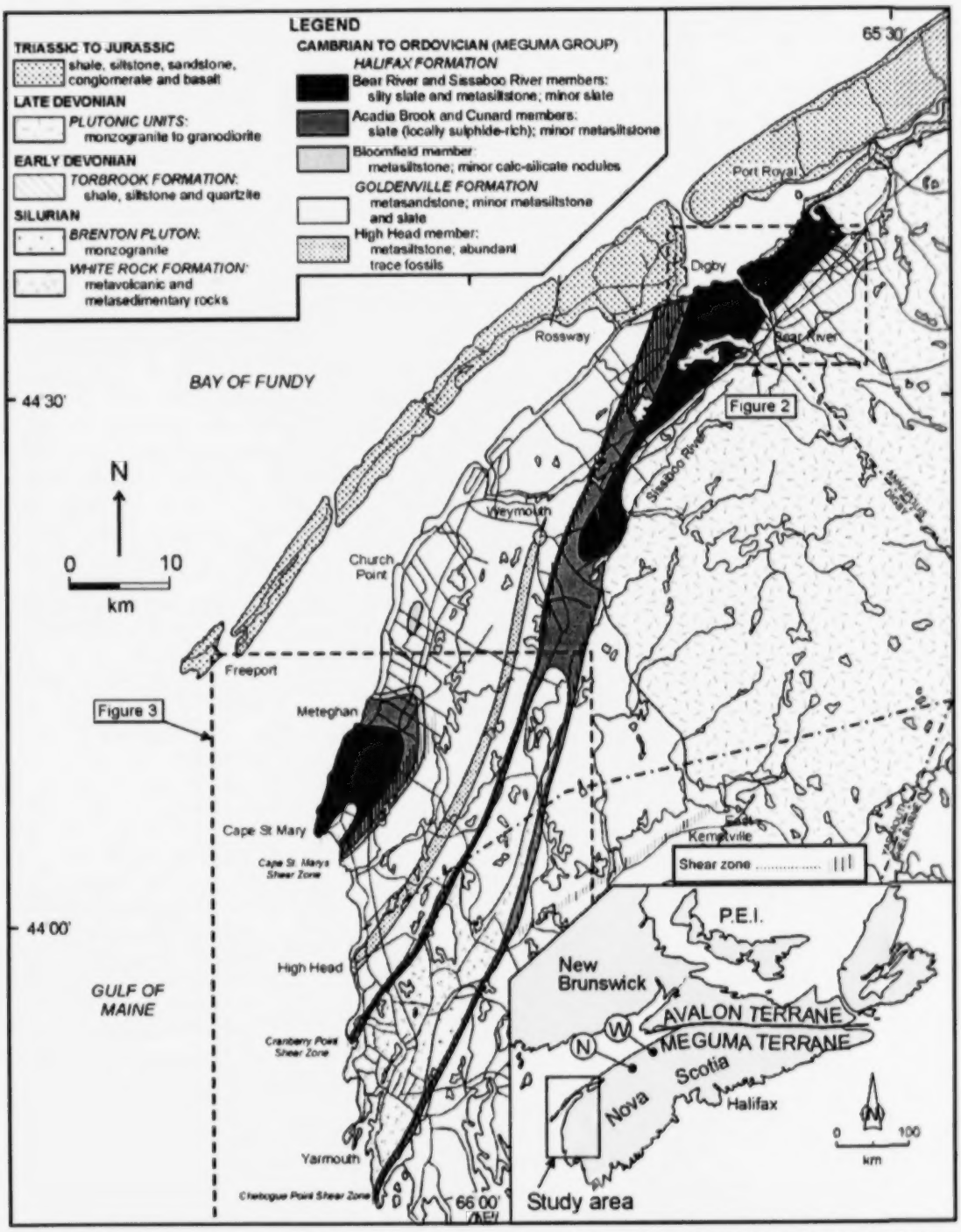


Figure 1. Simplified geology map of the Bear River – Yarmouth area of southwestern Nova Scotia showing locations of the Bear River and Mavillette - High Head areas (in boxes). Inset map shows the location of the Wolfville-Kentville (W) and Nictaux-Torbrook (N) areas.

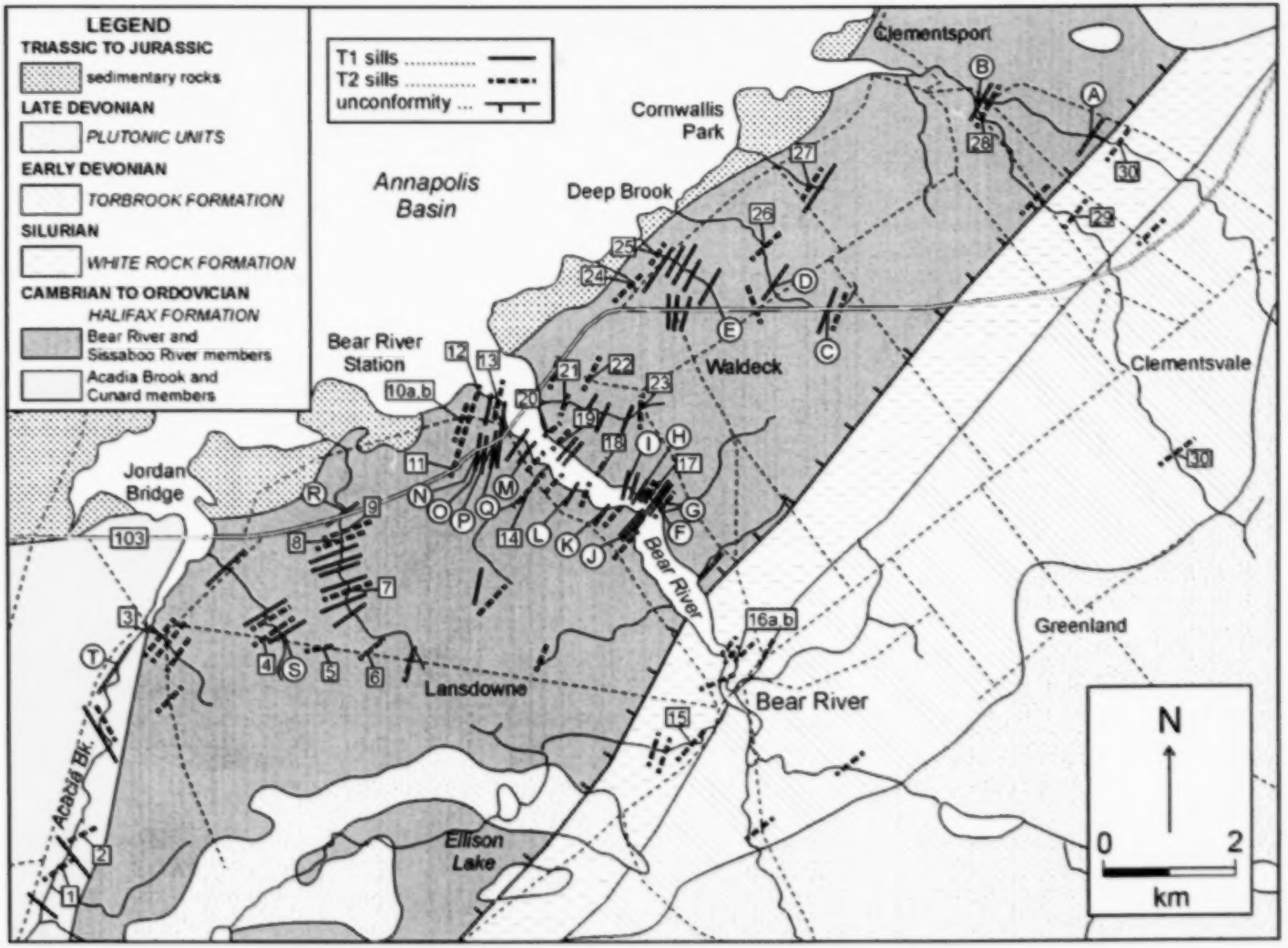
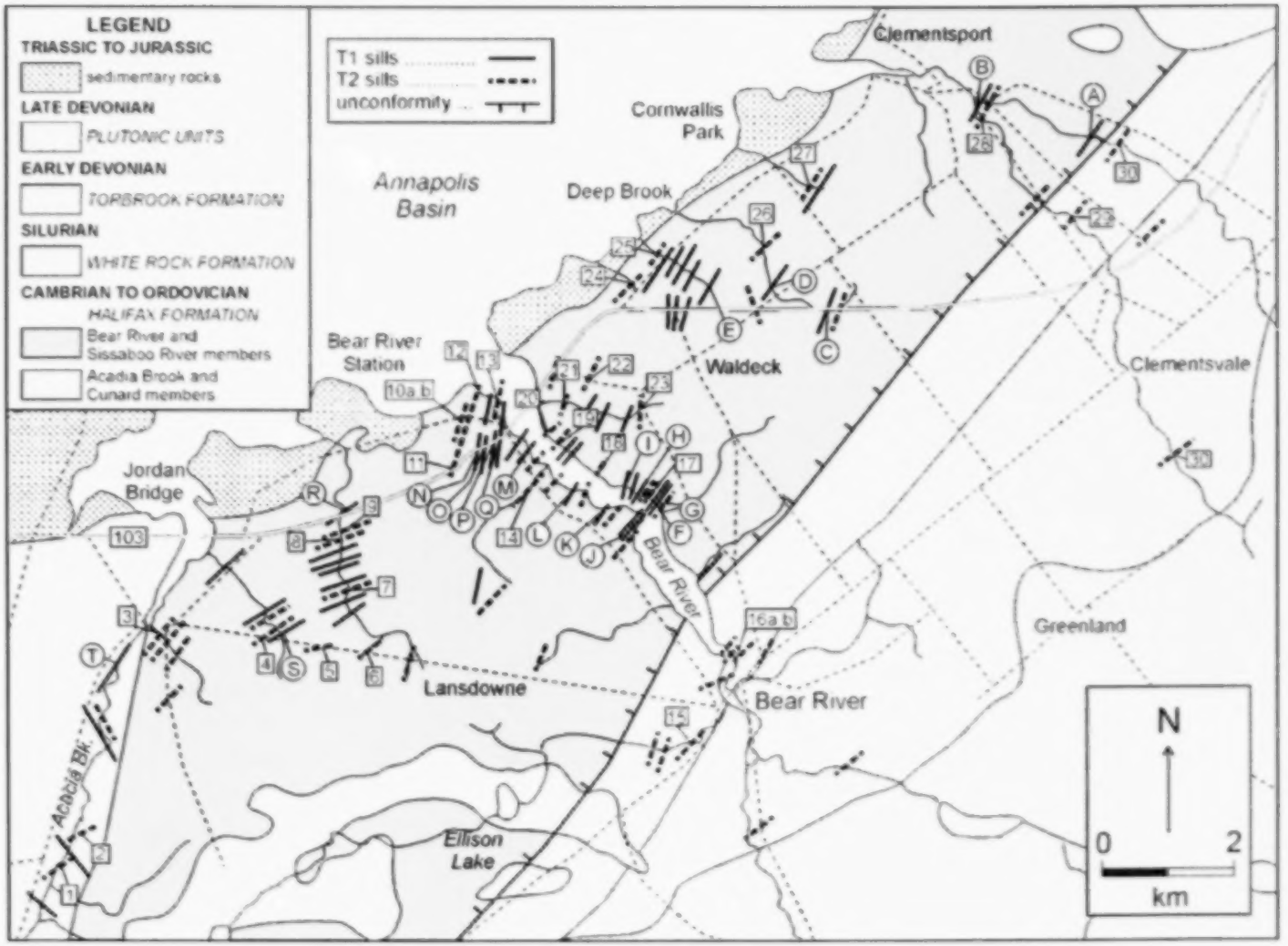


Figure 2. Simplified geology map of the Bear River area showing approximate locations and orientations of type I and type II sills. Locations of the geochemical samples A to T and 1 to 32 (Table 1) are shown.



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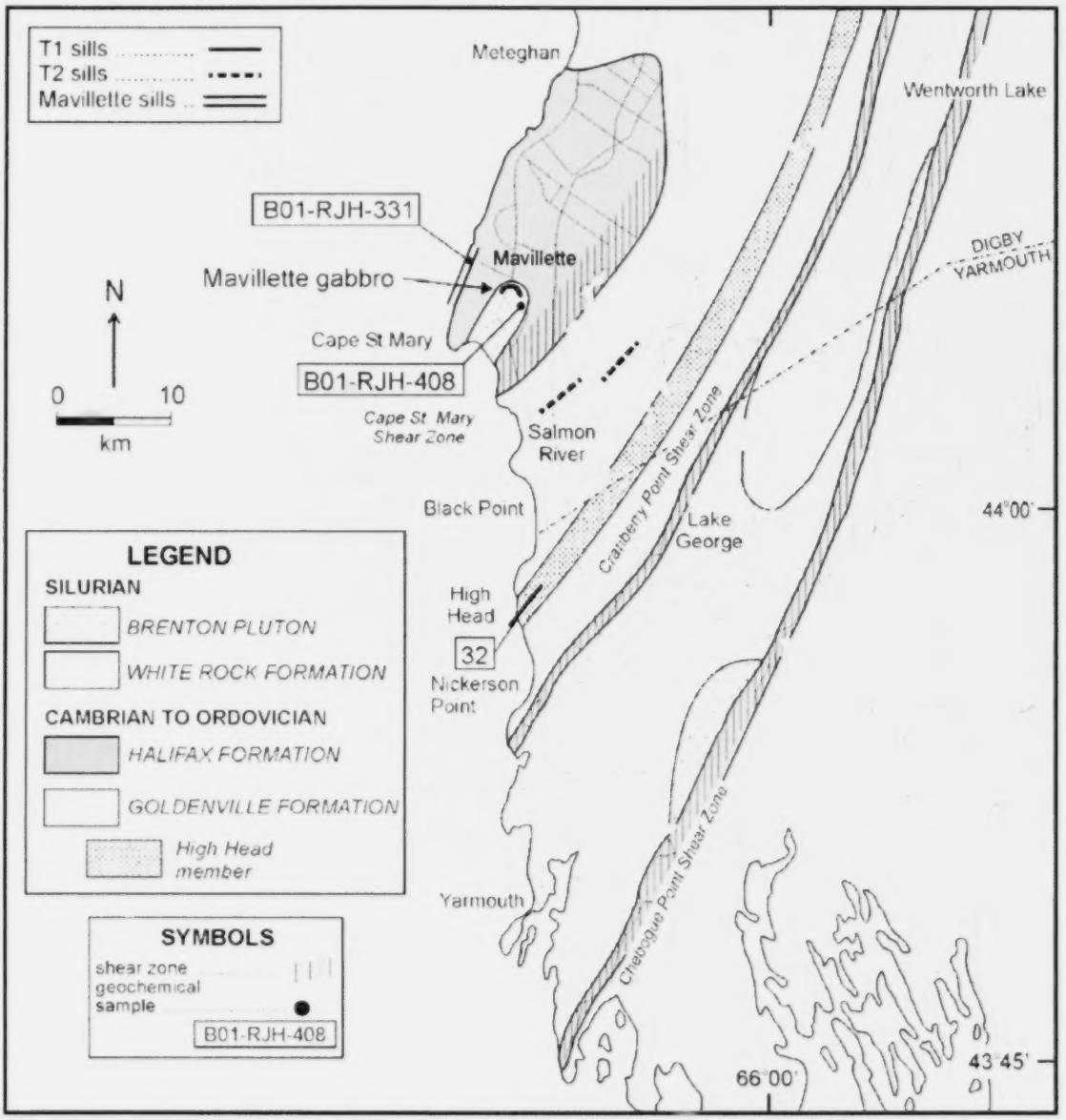

Figure 3. Simplified geology map of the Mavillette - High Head area showing approximate locations and orientations of Mavillette sill samples (B01-RJH numbers) and type I (32) and type II sills.

index species marking the Cambrian-Ordovician boundary (Cooper *et al.*, 2001), were reported from the uppermost beds exposed in the Bear River member (White *et al.*, 1999). In addition, units that are interpreted to represent the uppermost Halifax Formation elsewhere in the Meguma Group (Rockville Notch and Moshers Island formations) have yielded Tremadoc acritarchs (W. A. M. Jenkins, personal communication, 1977, in Schenk, 1995a).

Unconformably overlying the Halifax Formation in the Bear River and Weymouth areas are slate, metasiltstone and metasandstone of the

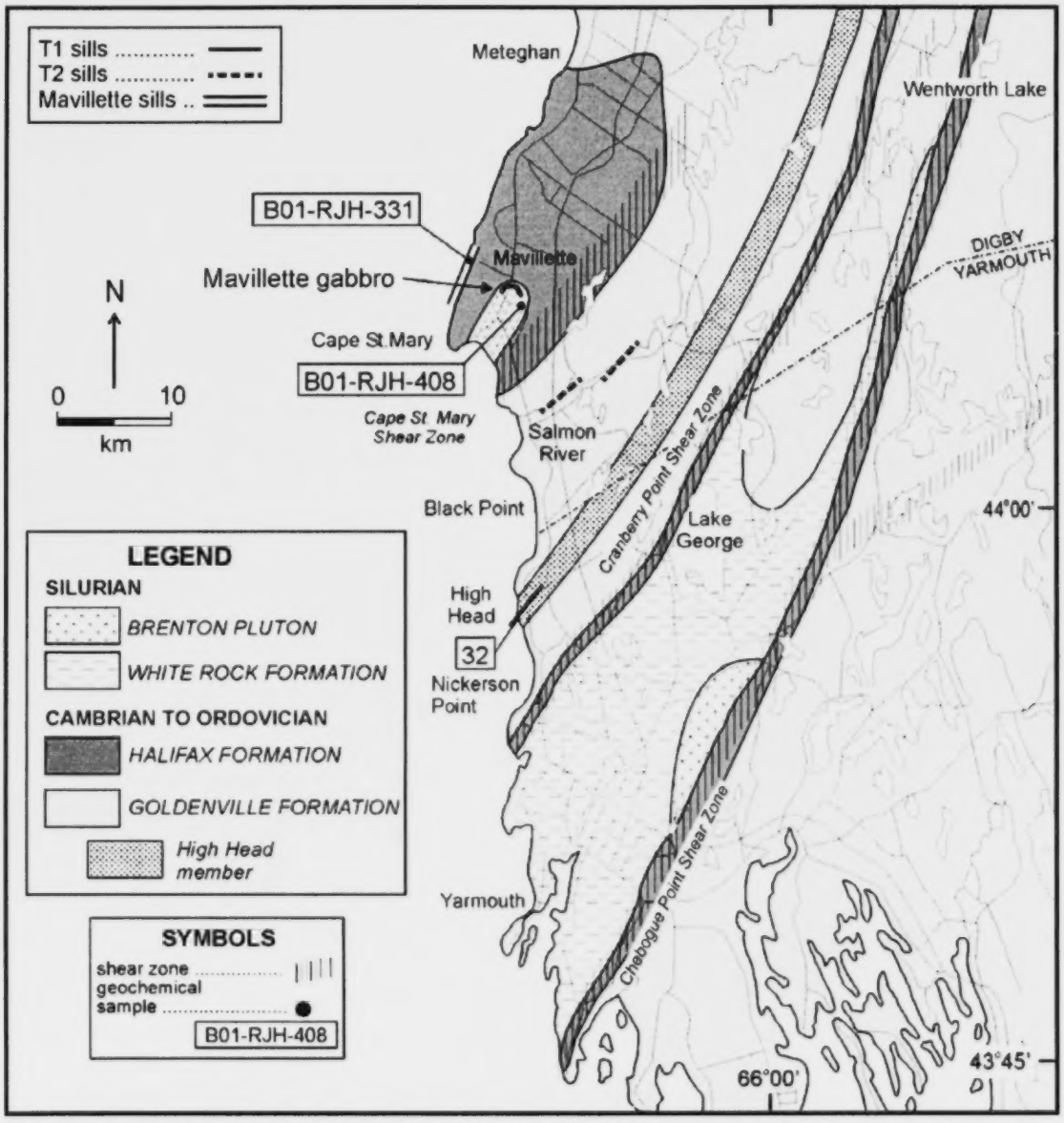

Figure 3. Simplified geology map of the Mavillette - High Head area showing approximate locations and orientations of Mavillette sill samples (B01-RJH numbers) and type I (32) and type II sills.

index species marking the Cambrian-Ordovician boundary (Cooper *et al.*, 2001), were reported from the uppermost beds exposed in the Bear River member (White *et al.*, 1999). In addition, units that are interpreted to represent the uppermost Halifax Formation elsewhere in the Meguma Group (Rockville Notch and Moshers Island formations) have yielded Tremadoc acritarchs (W. A. M. Jenkins, personal communication, 1977, in Schenk, 1995a).

Unconformably overlying the Halifax Formation in the Bear River and Weymouth areas are slate, metasiltstone and metasandstone of the

White Rock Formation (White *et al.*, 1999; Horne *et al.*, 2000). Fossils from the upper part of this formation in the Bear River area were assigned to the Late Silurian by Blaise *et al.* (1991) and Bouyx *et al.* (1997). In contrast, the White Rock Formation in the Yarmouth area is composed mainly of metavolcanic rocks (Taylor, 1967; Hwang, 1985; MacDonald, 2000; White *et al.*, 2001; MacDonald *et al.*, 2002). Contacts with the underlying Halifax Formation are shear zones (Culshaw, 1994; Culshaw and Liesa, 1997; White *et al.*, 2001; Moynihan, 2003) that have yielded ca. 320 Ma muscovite ages, indicating a lower Pennsylvanian age for development (Culshaw and Reynolds, 1997; Moynihan, 2003). A felsic tuff from the upper part of the White Rock Formation in the Yarmouth area yielded a U-Pb zircon age of ca. 438 Ma (MacDonald *et al.*, 2002), whereas felsic crystal tuff at the base of the section in the Torbrook area yielded a similar U-Pb (zircon) age of 442 ± 4 Ma (Keppie and Krogh, 2000). Recently discovered fossils from near the base of the formation in the Yarmouth area suggest that the formation in that area may extend down into the Ordovician, but is dominantly Silurian (A. Boucot, written communication, 2004).

Gradationally overlying the White Rock Formation in the Bear River, Torbrook and Weymouth areas are metasiltstone, slate, metasandstone and marble of the Early Devonian Torbrook Formation (Smitheringale, 1973; White *et al.*, 1999; Horne *et al.*, 2000; Bouyx *et al.*, 1997). Numerous mafic sills and rare dykes intrude the Meguma Group and White Rock and Torbrook formations but not the South Mountain Batholith. These sills are described in more detail below.

The Meguma Group, White Rock Formation and Torbrook Formation (and mafic sills) were deformed during the Devonian Acadian Orogeny. Deformation resulted in regional-scale northeastward-trending folds with an axial planar cleavage and regional greenschist facies metamorphism (Taylor, 1969; Smitheringale, 1973; White *et al.*, 1999; Horne *et al.*, 2000). All of these units were intruded by late syntectonic, medium- to coarse-grained monzogranite and granodiorite of the Late Devonian South Mountain Batholith and the Ellison Lake and Clayton Hill plutons (Allen and Barr, 1983; MacDonald *et al.*, 1992; Ham, 1994; White *et al.*, 1999; Horne *et al.*, 2001).

Mafic Sills

Introduction

Two prominent sets of mafic sills are present in the map area (Fig. 1). Type I sills are restricted to the Meguma Group and are inferred to be penecontemporaneous with their host rocks and, therefore, latest Neoproterozoic to Early Ordovician in age. Type II sills intrude the Meguma Group as well as the White Rock and Torbrook formations, but predate the South Mountain Batholith, Ellison Lake Pluton and Clayton Hill Pluton; hence, they are early to middle Devonian in age. A third set of mafic sills was recognized, which are texturally and mineralogically similar to Mesozoic basalt of the North Mountain Formation. These probable Mesozoic sills are not common and will not be discussed further here. Based on limited data, type I and II sills were interpreted by Barr *et al.* (1983) to be tholeiitic transitional to alkalic, with the older sills more alkalic in character, and speculated to have been emplaced in a continental, within-plate environment.

Type I Sills

Type I sills are typically light grey and fine-grained with an average thickness of 2 m, rarely exceeding 3 m (Fig. 4). They are concordant with bedding but are not laterally extensive, typically pinching out along strike. Dykes similar to type I sills are rare; however, locally some sills bifurcate and cut across bedding or cut up-section to another bedding surface. Typically the sills display fine-grained to glassy (now altered) chill margins at the top and bottom of the sill. They are also commonly vesicular and locally show multiple intrusions one into another (e.g. Doyle 1979, plate 3-3, p. 54). One sill in the Bloomfield member had a pronounced amygdaloidal margin towards the inferred top of the sill and in the High Head member along the coast (Fig. 3) a thin sill displays peperite-like structures along its lower contact with the country rocks (Fig. 5a). Some sills in the Bear River member along the Bear River Estuary display

irregular contacts or interfinger with the host sedimentary rocks (Doyle, 1979; Barr *et al.*, 1983), and laminations in the slate and sill contacts are in places highly contorted (Fig. 5b). These relationships suggest that sill emplacement was penecontemporaneous with deposition of the Meguma Group.

Type I sills are highly altered with only relict igneous textures preserved (e.g. flow alignment defined by pesudomorphed euhedral plagioclase, porphyritic and glomeroporphyritic textures) and no igneous minerals. Phenocrysts displaying clinopyroxene, olivine and rare biotite morphologies are completely pseudomorphed by carbonate minerals, chlorite, and other secondary minerals. Magnetite and ilmenite vary in abundance and probably include both primary and secondary crystals (Doyle, 1979; Barr *et al.*, 1983). The variable, but low magnetic susceptibility (less than $1x10^{-3}$ SI) reflects this (Fig. 6). It is unclear from the texture and mineralogy if the alteration is a result of deuteric and autometasomatic processes such as those described by Poage *et al.* (2000) or later regional/retrograde metamorphism.

Type I sills, together with the Meguma Group, have been deformed into F1 folds (Fig. 5c). The sills are characterized by upright, subhorizontal to shallowly northeast-plunging, northeast-trending folds with a steep axial planar cleavage (Fig. 7a). These structures mimic those in the folded country rocks (Fig. 7b) and indicate that the sills were originally emplaced horizontally along bedding planes in the Meguma Group.

Type II Sills

Type II sills are dark grey to black, medium- to coarse-grained, and generally wider (rarely less than 5 m and typically greater than 10 m) and less abundant than type I sills (Fig. 4). Type II sills occur in the Goldenville, Halifax, White Rock and Torbrook formations, but have not been observed in the South Mountain Batholith or Ellison Lake

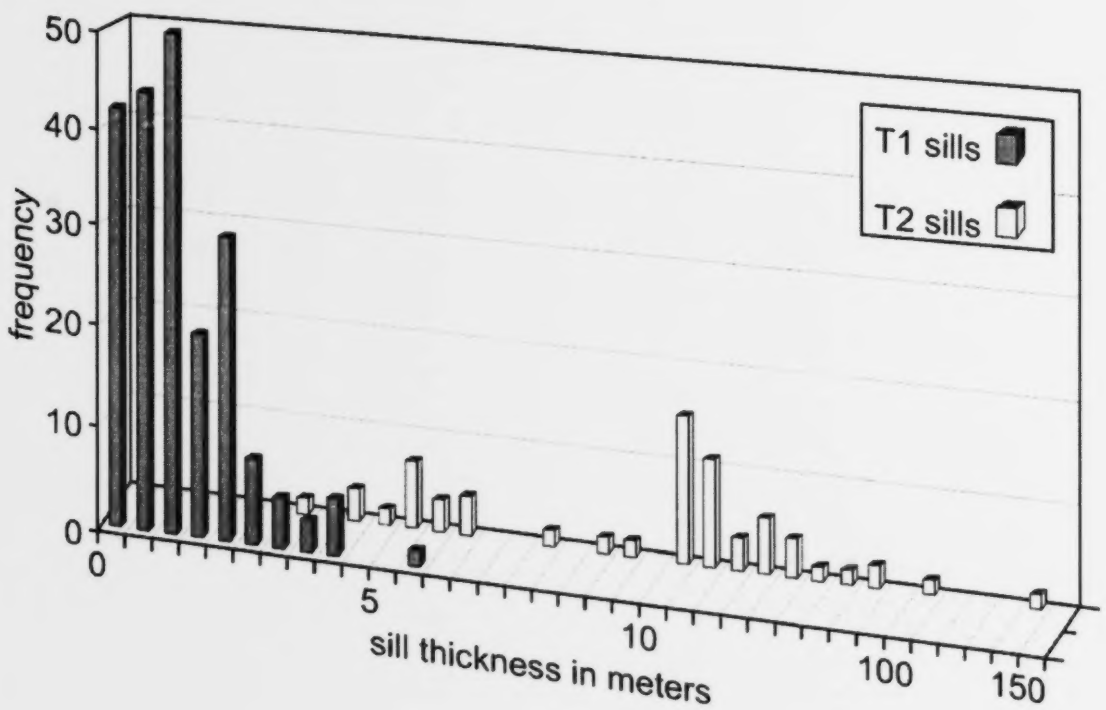

Figure 4. Histogram of type I (n=223) and type II (n=66) sill widths. Note the change of scale for thicknesses greater than 10 m.

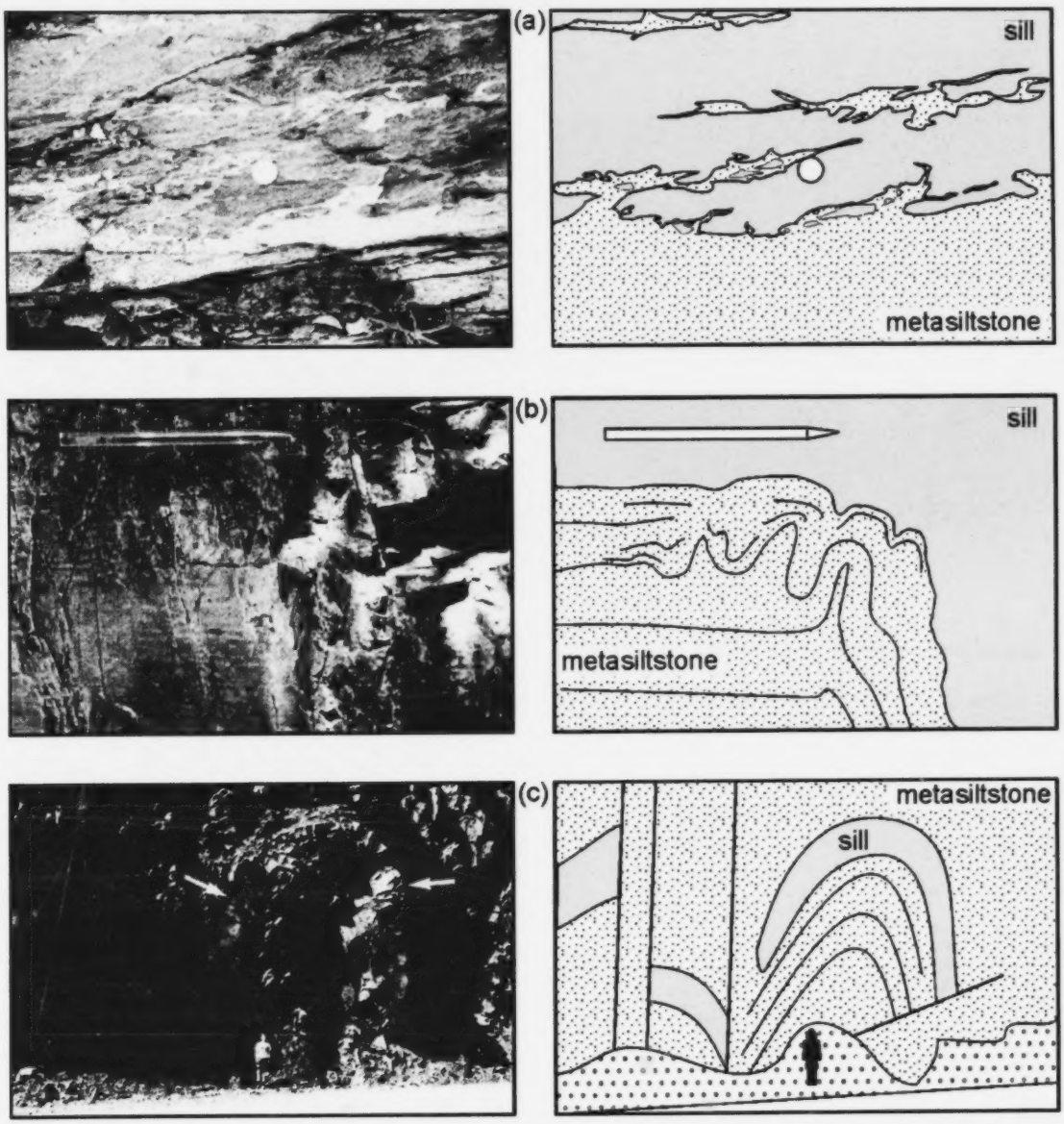

Figure 5. Photographs with line drawing of (a) lower contact of a type I mafic sill displaying peperitic features, High Head member of the Goldenville Formation exposed at High Head, quarter for scale (b) lower contact of a type I mafic sill with contorted sedimentary laminations in the host metasiltstone, Bear River member on Bear River, pen is 14 cm long and (c) typical mesoscopic fold in silty slate of the Bear River member with a folded type I sill (arrows), highway interchange at mouth of Bear River.

and Clayton Hill plutons. In the Bear River section, mafic sills are most abundant near the top of the White Rock Formation. Interbedded slates along strike yielded Late Silurian fossils (Blaise *et al.*, 1991; Bouyx *et al.*, 1997). Like type I sills, type II sills are typically concordant with bedding; however, some are slightly cross-cutting but still subparallel to bedding. In contrast to type I sills, type II sills are laterally extensive, up to several 100s of m in strike length. Most display well developed chill margins, but are typically less vesicular than the type I sills. No structures indicative of syn-sedimentary sill emplacement, like those in type I sills, were observed.

Type II sills are considerably less altered than type I sills. Igneous textures and minerals are generally well preserved. Sills are typically characterized by abundant partially saussuritized euhedral plagioclase (andesine-labradorite) with lesser amounts of subhedral clinopyroxene (augite). Some samples, however, contain no primary clinopyroxene and if it ever existed, all evidence has been overprinted by the growth of secondary minerals (chlorite, epidote and calcite). Green to blue-green amphibole is rare and where present it rims clinopyroxene. Euhedral to interstitial red-brown biotite is common and partially to entirely replaced by chlorite. Serpentinized olivine pseudomorphs were observed in some samples. Apatite and opaque minerals are common. Typically the type II sills are fine- to medium-grained, rarely coarse grained, and display an ophitic to subophitic texture. Intergranular textures are not common (Barr *et al.*, 1983). Generally, the magnetitic susceptibility levels are similar to those in the more altered type I sills (Fig. 6). This similarity suggests that either there was initially little difference in the magnetic mineral content of the two sill types, or more likely, that alteration affected magnetic minerals similarly in all the sills (c.f. Doyle, 1979).

Folded type II sills were not observed; however, many of the sills are deformed and cleaved suggesting that, like the type I sills, they were folded during regional deformation in the Acadian Orogeny (Fig. 7c).

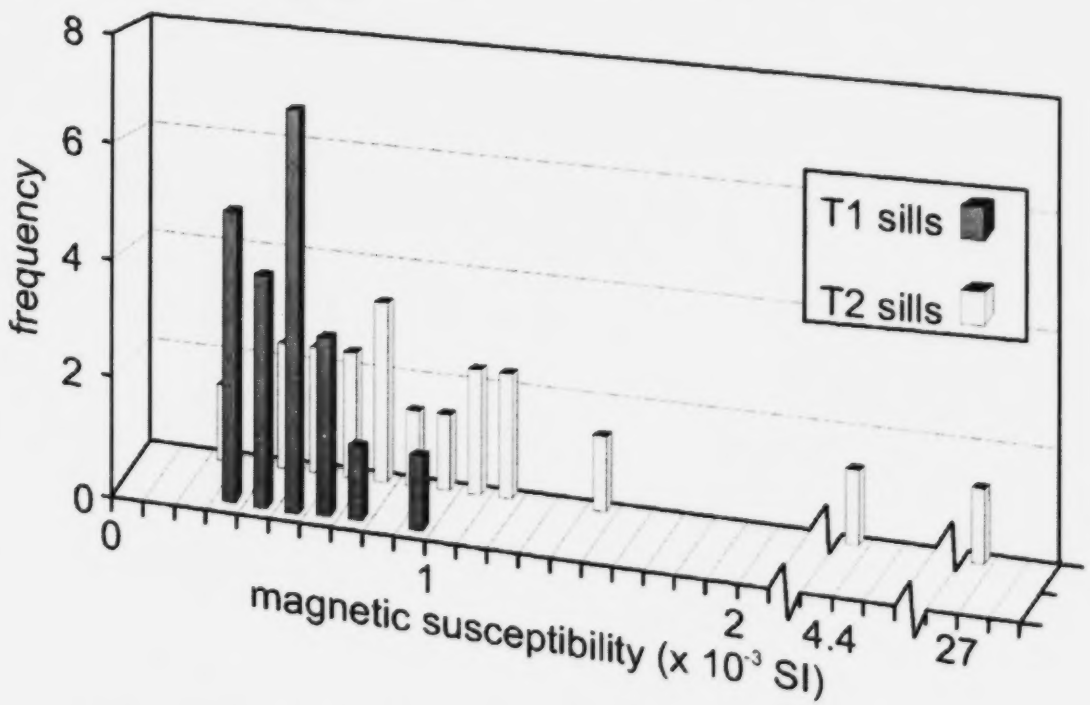

Figure 6. Histogram of type I and type II sill magnetic susceptibility measurements.

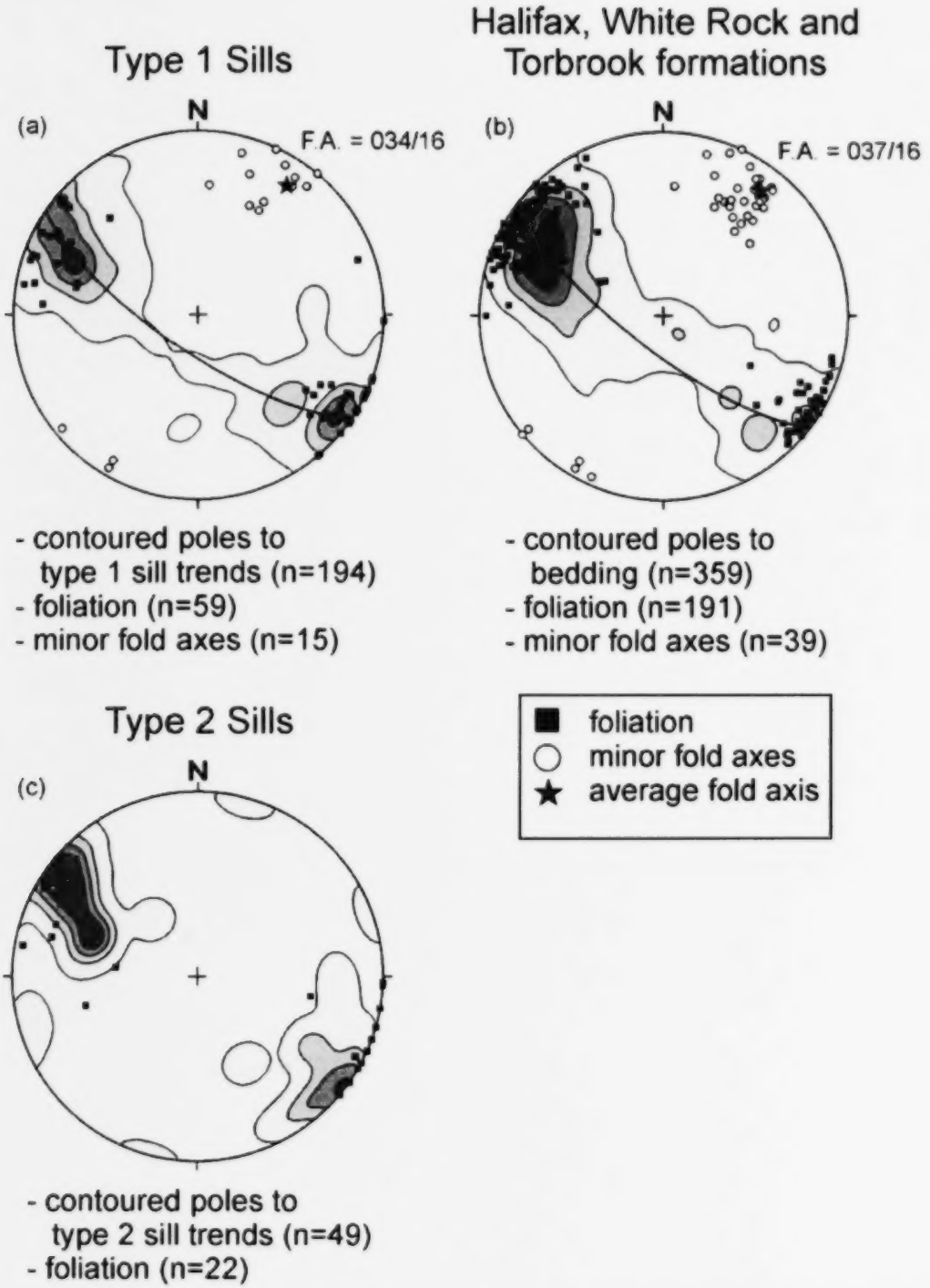

Figure 7. Stereographic projections displaying the main structural data from the study area. (a) contoured poles to type I sill trends. (b) contoured poles to bedding. (c) contoured poles to type II sill trends. Contours on the stereonets at 1, 3, 5, and greater than 7% per 1% area; darkest shading indicates highest contour area.

Geochemistry

Chemical data were compiled from the earlier work of Doyle (1979) and Barr *et al.* (1983), with additional trace element data acquired on 15 samples for which sufficient powder was available. Major element analyses were redone in 9 of the samples in order to check on the quality of the older data. In general, the precision of the major element data is within 10%, adequate for the purposes of this study. Table 1 is a compilation of chemical data from the sills as used in the discussion below.

Many of the analyzed samples have high loss-on-ignition levels (5-10%), consistent with the high abundance of hydrous phases and carbonate minerals. Hence, to facilitate comparisons, the major element oxides were recalculated to total 100% volatile-free before plotting on the diagrams.

Recalculated SiO_2 contents are between 46 and 54% in most samples; a few of the type I sills and one of the sills from the Mavillette area have somewhat lower levels (Fig. 8a). To illustrate the overall chemical characteristics of the samples, and compare them to gabbroic and mafic volcanic rocks from elsewhere in the study area, the data are plotted against FeO^t/MgO ratio as an indication of the degree of magma differentiation (Figs. 8, 9). Although the spread in FeO^t/MgO ratio is limited in the sills, the samples display weak trends of increasing TiO_2, Al_2O_3, Na_2O, and P_2O_5 and decreasing MgO with increasing FeO^t/MgO (Fig. 8). SiO_2, Fe_2O_3, CaO, Na_2O, and K_2O are scattered and do not show any consistent variation with FeO^t/MgO ratio. The type I and type II sills, and the sill in the Goldenville Formation at High Head, do not show any consistent differences in their major element chemical compositions.

In comparison to the Mavillette Gabbro, the sills generally have lower FeO^t/MgO ratio (Fig. 8). They generally have higher SiO_2 content compared to gabbro samples with low FeO^t/MgO ratio, and do not show the same degree of iron enrichment (increase in FeO^t/MgO ratio) with increasing SiO_2 (Fig. 8a). However, taken together, the sill and Mavillette gabbro samples form coherent trends on the variation diagrams. These trends are reasonably consistent with the gabbro being a more evolved product from a similar parental magma, in that the sill samples with highest FeO^t/Mg ratios tend to overlap with the gabbro samples with lowest FeO^t/MgO ratios (Fig. 8). Spread in the mobile element oxides CaO, Na_2O, and K_2O in the sill samples may be largely the result of alteration. The two sills in the Mavillette area are most similar to the Mavillette Gabbro in composition, as noted previously by White *et al.* (2003).

Trace element compositions are also similar between the type I, type II, and High Head sills, and the sills in the Mavillette area are similar in composition to the Mavillette Gabbro (Fig. 9). Compared to the Mavillette Gabbro and sills, the type I and type II sills tend to have higher Y, Zr, and Nb, lower V, and a wider range in Rb and Sr, the latter likely due to alteration (Fig. 9a - f). The sills range to higher Ni, Cr, and Cu values than the gabbro.

The sills show more similarity to mafic volcanic rocks and related dykes of the White Rock Formation in the Yarmouth area than to the Mavillette Gabbro. The White Rock Formation samples show less variation in SiO_2 and a wider range in FeO^t/MgO ratios, but overlap considerably in other chemical components. The similarity is apparent in the more limited range in FeO^t/MgO ratio, and positive correlations between FeO_t/MgO ratio and TiO_2 and Fe_2O_3 (Fig. 8b, d). Trace element compositions are also more similar, especially notable in Y, Zr, V and Zn (Fig. 9a, b, f, i).

The sills show a trend between subalkalic and alkalic basalt on the basis of Nb/Y ratio (Fig. 10a), with a few samples with particularly high Nb/Y ratios extending into the highly alkalic basanite/nephelinite fields. In terms of most chemical criteria, the sills appear transitional between tholeiitic and alkalic compositions, such as displayed on the Ti-V diagram (Fig. 10b), although V data are available from relatively few samples. The iron- and TiO_2-enrichment trends displayed by the samples (Fig. 8b), as well as V and Ti relations (Fig. 10b) show that the sills are not calc-alkalic. Continental tholeiitic affinity is strongly indicated by TiO_2 and Y/Nb variations

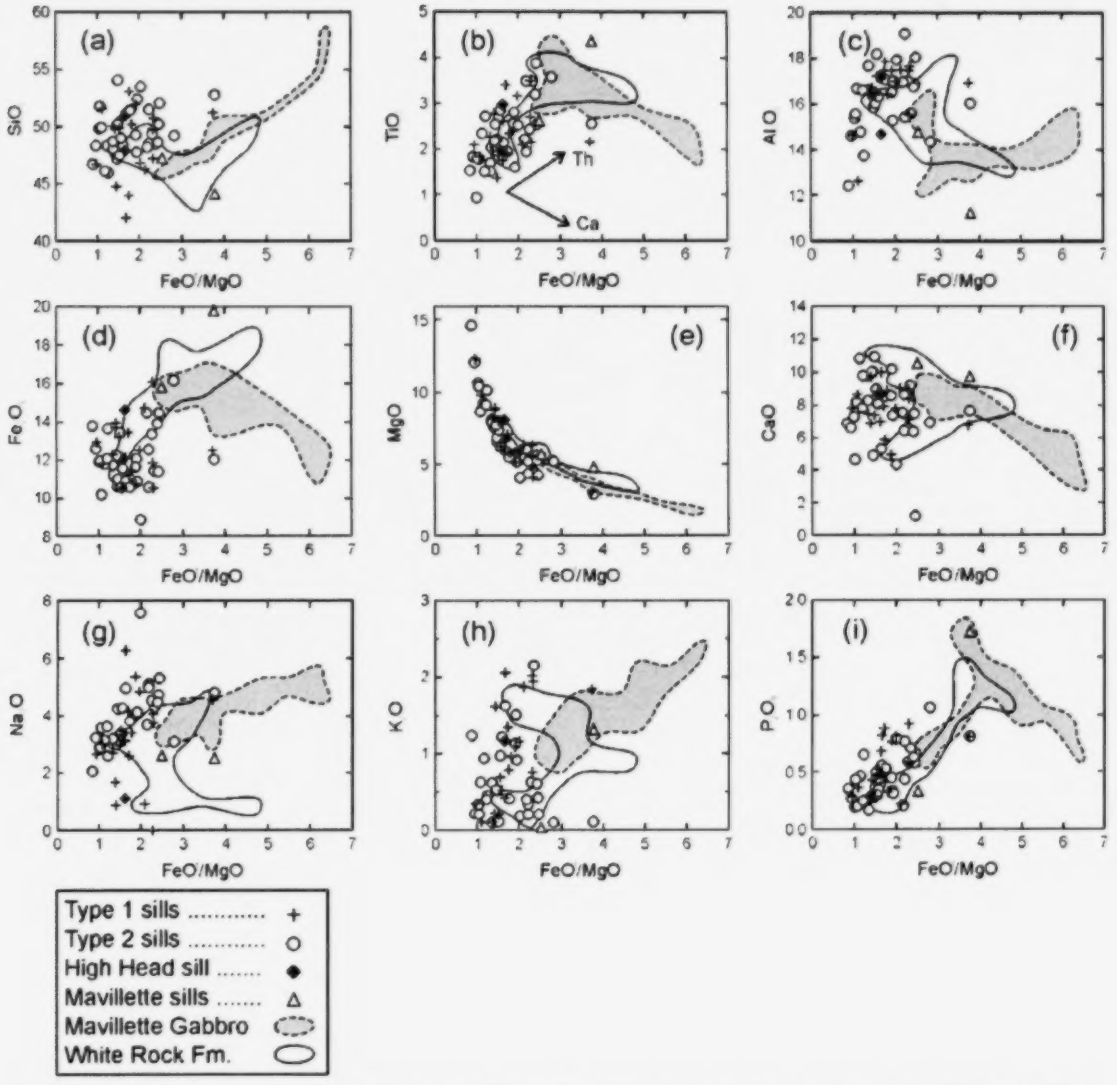

Figure 8. Plots of major element oxides against FeO^t/MgO to illustrate chemical variation in the type I, type II, Mavillette, and High Head sills. Chemical data are from Table 1. Also shown are fields for the Mavillette gabbro (after White *et al.*, 2003) and mafic flows and dykes in the White Rock Formation in the Yarmouth area (after MacDonald *et al.*, 2002). Tholeiitic (Th) and calc-alkalic (Ca) trends in (b) are after Miyashiro (1974).

(Fig. 10c), with relatively few samples plotting in the alkalic field. Although distinction between tholeiitic and alkalic affinity is not unequivocal, a within-plate tectonic setting is clearly indicated by a variety of discrimination diagrams (Figs. 10d, e, f). Both the Mavillette Gabbro and Yarmouth area samples show chemical characteristics and tectonic setting similar to that of the sills. Overall, all of these rocks have features that suggest they were formed in a within-plate extensional environment in an area underlain by continental crust.

Discussion

The Goldenville Formation is interpreted to represent

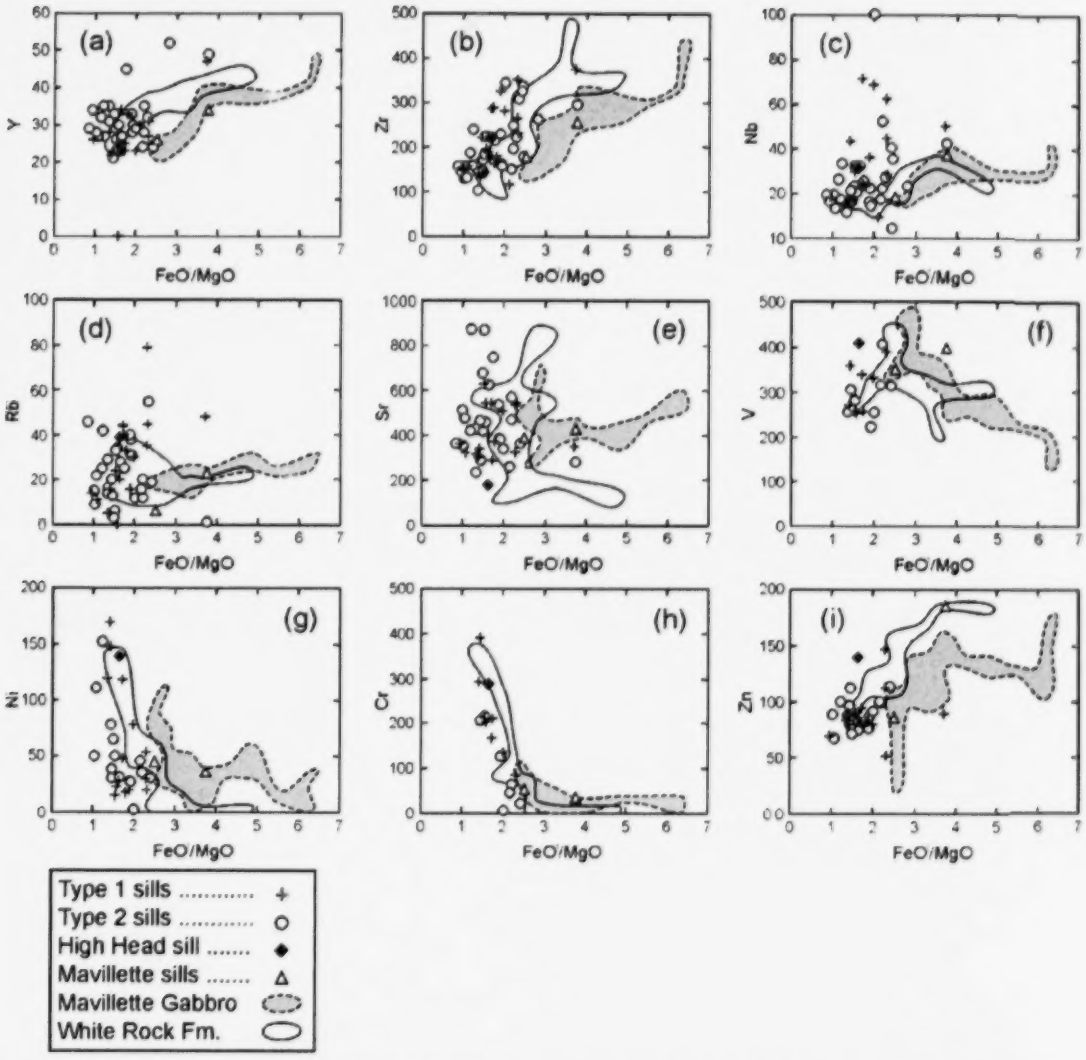

Figure 9. Plots of trace elements against FeO^t/MgO to illustrate chemical variation in type I, type II, Mavillette, and High Head sills. Chemical data are from Table 1. Also shown are fields for the Mavillette gabbro (after White *et al.*, 2003) and mafic flows and dykes in the White Rock Formation in the Yarmouth area (after MacDonald *et al.*, 2002).

an abyssal plain fan deposit, formed by sedimentation related to turbidity currents, whereas the younger Halifax Formation represents turbiditic deposition in the lower part of a continental-rise prism that prograded northwestward (present-day coordinates) over the Goldenville fan deposit (Waldron and Jensen, 1985; Schenk 1991, 1995a, 1997; Waldron, 1992). Based on comparisons with modern continental margins in ocean basins, deposition of the Meguma Group probably occurred on continental and oceanic crust, including the transition zone between the two (Fig. 11a). In present day coordinates, the ocean floor with oceanic basement (if present) would have existed farther to the northwest.

Based on paleontological constraints presented in this paper and compiled from older work (summarized in Schenk 1995a), the type I sills in the study area were emplaced during

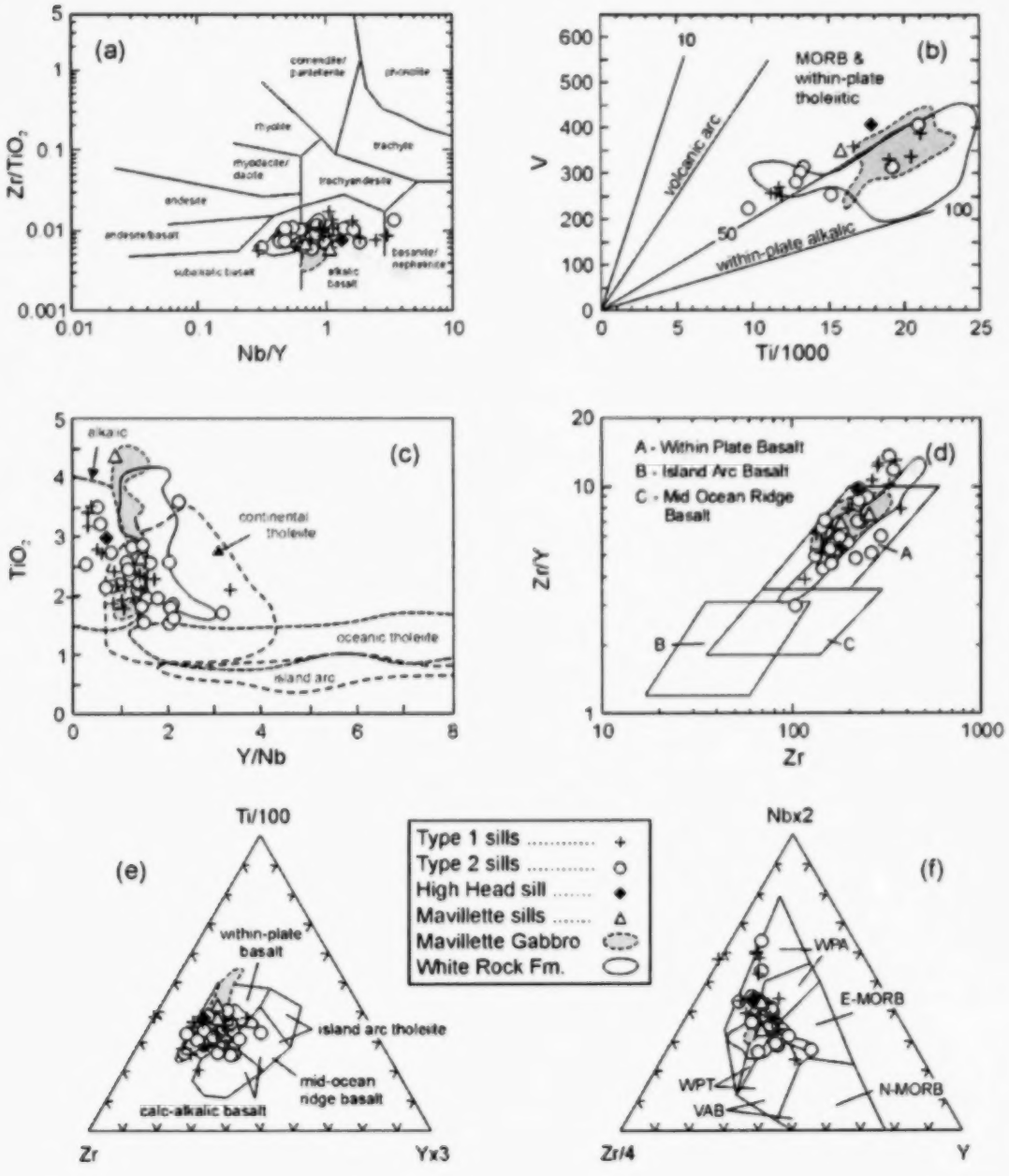

Figure 10. Plots of (a) Zr/TiO_2 against Nb/Y, (b) V against Ti, (c) TiO_2 against Y/Nb, (d) Zr/Y against Zr, (e) Ti-Zr-Y, and (f) Nb-Zr-Y in type I, type II, Mavillette, and High Head sills. Chemical data are from Table 1. Also shown are fields for the Mavillette gabbro (after White *et al.*, 2003) and mafic flows and dykes in the White Rock Formation in the Yarmouth area (after MacDonald *et al.*, 2002). Fields are from (a) Winchester and Floyd (1977), (b) Shervais (1982), (c) Floyd and Winchester (1975), (d) Pearce and Norry 1979, (e) Pearce and Cann (1973), and (f) Meschede (1986).

deposition of turbiditic sequences over a span of time that extends from the lower (latest Neoproterozoic) part of the Goldenville Formation through to the upper (earliest Ordovician) part of the Halifax Formation, a time span of about 70 million years (following the geological time scale of Okulitch, 2002). Field evidence, including soft-sediment deformation at the sill contacts and deep-water trace fossils, suggests that the type I sills were emplaced at shallow levels into wet, continentally derived sediments in extremely deep water. The lack of volcanic rocks related to the sills in the Meguma Group stratigraphy is not surprising: type I sills are thin and limited in lateral extent, and were intruded into wet, cold sediments. Type I sills would have crystallized very quickly under these conditions. Several examples exist in the literature of mafic sills intruded into wet sediments and lacking extrusive equivalents (e.g. sills in the Prichard Formation of the Belt-Purcell Supergroup; Poage *et al.*, 2000).

Following a hiatus of about 35 million years (Middle and Upper Ordovician), the environment changed from a deep-water slope and abyssal plain setting to the shallow-marine setting represented by the Silurian White Rock Formation (Fig. 11b), followed by deposition of the shallow-marine Early Devonian Torbrook Formation (Fig. 11c). The timing of type II sill emplacement is unclear. In the Yarmouth area some mafic sills in the Goldenville and Halifax formations are chemically related to the Mavillette Gabbro and are synchronous with mafic volcanic activity in the White Rock Formation (White *et al.*, 2003). The White Rock and Torbrook formations in the Bear River area do not have any volcanic rocks and the type II sills intrude both formations but are most abundant in the upper part of the White Rock Formation. Although volcanic rocks are abundant in the lower White Rock Formation elsewhere in the Meguma Group (Fig. 11 *in* MacDonald *et al.*, 2002) these upper White Rock Formation sills are equivalent in age to the volcanic rocks of New Canaan Formation exposed to the northeast, which has yielded late Silurian fossils (Bouyx *et al.*, 1997). Like the White Rock Formation, volcanic rocks of the New Canaan Formation have within-plate characteristics, but are more strongly alkalic than the type II sills (James, 1998).

Although it has been speculated that the White Rock and Torbrook formations extended across the entire Meguma terrane (Schenk, 1995b), these formations together with the contained mafic sills now form a narrow, long belt that extends for more than 250 km along the northwestern margin of the terrane. This may indicate some structural control on where these extensional features were formed. Based on sediment dispersal directions summarized in Schenk (1997), sediments moved northwestward into the basin. The presence of deep water, abyssal plain trace fossils in the High Head member confirms that the deepest part of the basin was to the northwest. Based on comparisons with modern ocean basins, the thinned continental crust slope-rise area as it transitions into oceanic crust would provide an ideal location for rift-related magmatism as the continental crust to the southeast would be considerably thicker (Fig. 11a, b, c).

The similarity in within-plate tholeiitic to alkalic characteristics of the type I sills, the Mavillette Gabbro, mafic volcanic rocks in the White Rock Formation and type II sills, indicates that an extensional tectonic regime existed along the northwestern margin of the Meguma Terrane in southwestern Nova Scotia over a period of about 150 million years. Incipient continental rifting started in the latest Neoproterozoic and culminated with a major extensional period in the Silurian, with deposition and volcanism related to the White Rock Formation. Extension then continued well into the Early Devonian. Although the major Silurian extensional event may represent separation of the Meguma terrane from Gondwana (van Staal *et al.*, 1998), extension recorded in the White Rock Formation likely represents a failed continental rift setting as rocks of the Meguma Terrane are on both sides of the formation.

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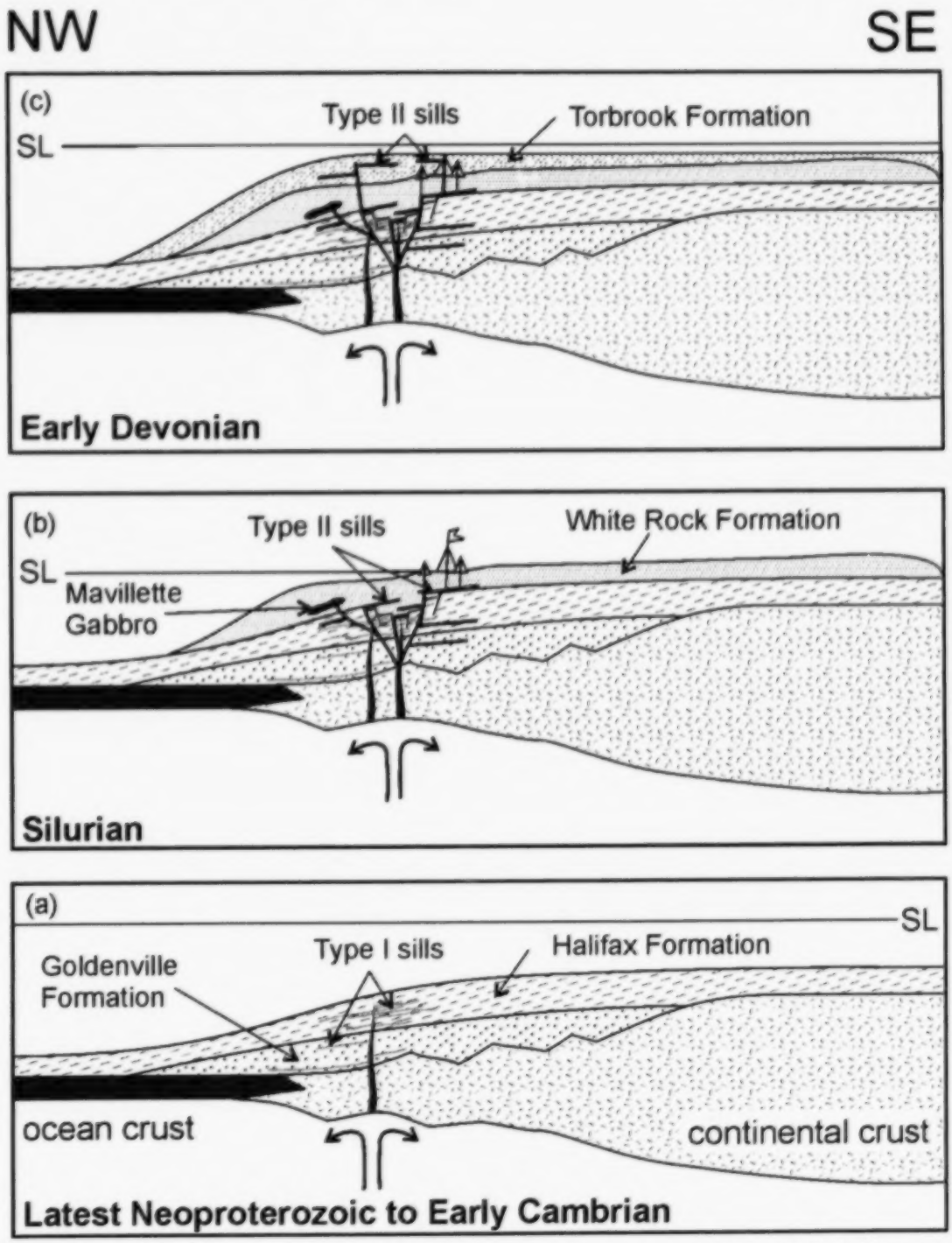

Figure 11. Idealized schematic cross-section of the inferred continental margin - ocean basin on which the Meguma Group, White Rock and Torbrook formations were deposited. (a) Latest Neoproterozoic to Early Cambrian time slice for deposition of the Goldenville and Halifax formations and sill emplacement. (b) Silurian time slice for deposition of the White Rock Formation and sill emplacement. (c) Early Devonian time slice for deposition of the Torbrook Formation and continued sill emplacement.

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Table 1. Geochemical data from type I and type II sills[1].

Map#	Sample #	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O5	LOI	Total
A*	ED79-255	43.54	2.69	16.24	13.62	0.20	8.63	9.39	0.87	1.56	0.42	2.60	99.76
B	ED79-243	47.30	2.00	15.60	11.60	0.16	2.80	6.20	4.20	1.70	0.75	9.10	101.41
C	ED79-213	47.20	2.20	15.40	10.80	0.17	5.40	8.30	3.20	0.90	0.31	6.80	100.68
D	ED79-203	42.00	2.40	13.80	14.40	0.20	5.60	7.90	0.00	1.80	0.82	14.50	103.42
E	ED79-150	46.90	1.30	15.40	12.50	0.16	7.50	6.90	2.80	0.20	0.27	8.50	102.43
F	ED79-483b	46.30	2.10	15.20	11.40	0.15	7.60	6.80	2.50	0.10	0.27	4.70	97.12
G*	ED79-458x	49.35	1.78	16.58	10.48	0.35	5.41	5.40	2.42	0.73	0.39	6.87	99.76
H	ED79-454a	48.60	1.70	16.30	11.60	0.16	6.40	6.60	3.00	0.40	0.65	6.50	101.91
I	ED79-464b	47.40	1.70	11.60	10.90	0.16	9.00	7.90	2.80	0.10	0.34	8.00	99.90
J*	ED79-109b	48.90	1.79	16.57	10.15	0.16	5.96	8.22	3.37	0.66	0.47	3.53	99.77
K*	ED79-448e	45.91	3.24	16.08	10.97	0.15	4.29	6.51	3.76	0.69	0.54	7.83	99.98
L*	ED79-P16II	45.89	1.80	15.22	12.68	0.18	8.07	6.30	1.57	0.20	0.25	8.50	100.66
M*	ED79-012a	37.43	2.90	14.84	11.48	0.22	6.02	6.69	3.53	1.15	0.75	13.50	98.51
N	ED79-002j	36.90	2.30	15.00	10.70	0.20	5.80	8.70	5.50	1.80	0.72	13.70	101.32
O*	ED79-002L	41.77	2.82	15.13	11.18	0.14	5.05	6.90	4.31	1.03	0.73	10.81	99.87
P	ED79-002p	47.60	2.20	16.00	9.90	0.11	4.70	4.50	4.90	1.00	0.71	8.19	99.81
Q	ED79-002v	44.60	1.90	15.50	9.30	0.15	3.60	7.30	3.30	1.70	0.50	11.80	99.65
R*	ED-79-018b	46.33	1.80	15.68	9.64	0.15	5.45	8.01	3.03	0.47	0.49	9.15	100.20
S	ED79-044	40.30	1.80	12.60	11.20	0.15	10.60	6.70	2.30	0.30	0.25	12.90	99.10
T	ED79-281	39.70	1.80	15.00	12.70	0.88	5.40	7.70	0.80	1.60	0.19	13.00	98.77
1	ED79-399	49.40	3.60	14.40	16.30	0.28	5.20	6.90	3.10	0.10	1.06	0.90	101.24
2	ED79-397	47.60	1.80	17.60	9.80	0.19	4.00	5.90	4.70	0.30	0.41	6.70	99.00
3	ED79-438	49.40	2.40	15.00	11.30	0.23	2.70	7.10	4.50	0.10	0.76	5.80	99.29
4*	ED79-361	45.56	2.09	16.02	13.73	0.17	5.71	7.06	3.48	0.38	0.20	6.08	100.48
5	ED79-363	44.80	1.70	13.50	11.70	0.17	11.20	6.10	3.00	0.20	0.25	7.00	99.62
6*	ED79-139c	51.11	1.58	16.57	10.65	0.19	4.96	7.15	4.03	0.90	0.31	3.41	100.86
7	ED79-050a	42.70	2.00	14.40	11.00	0.17	6.60	9.80	2.80	0.10	0.33	9.40	99.30
8	ED79-024	47.50	2.00	15.90	10.20	0.15	5.50	4.90	4.60	1.50	0.52	6.20	98.97
9	ED79-025	39.40	2.00	12.60	10.10	0.19	7.90	9.20	2.70	0.80	0.40	15.40	100.69
10a	ED79-008a	47.80	1.50	16.40	12.00	0.17	9.00	7.70	3.60	0.40	0.25	3.50	102.32
10b*	ED79-008b	45.35	2.99	15.59	13.05	0.14	4.85	5.91	4.17	0.56	0.59	7.18	100.38
11	ED79-006	46.80	2.30	16.10	12.70	0.15	5.00	6.20	4.30	0.60	0.56	6.50	101.21
12	ED79-016a	48.40	2.00	15.70	10.30	0.16	6.30	9.60	3.10	0.50	0.27	4.60	100.93
13	ED79-001	50.90	2.40	14.90	10.40	0.14	6.40	4.60	4.00	0.10	0.27	5.20	99.31
14	ED79-106	48.00	1.70	16.60	12.10	0.17	8.10	9.70	3.20	0.10	0.17	2.10	101.94
15	ED79-297c	47.60	2.80	15.20	12.10	0.17	5.70	10.10	4.10	1.50	0.34	0.90	100.51
16a	ED79-493b	47.90	3.70	16.10	10.90	0.18	4.00	7.10	4.50	0.40	0.55	3.40	98.73
16b	ED79-493c				13.50		8.00				0.50		
17	ED79-451	48.30	1.70	14.50	11.20	0.15	9.70	4.30	2.70	0.20	0.41	6.80	99.96
18	ED79-3lg3	49.80	1.90	16.50	10.30	0.16	5.30	8.20	3.70	0.40	0.51	2.70	99.47
19*	ED79-311	45.92	2.13	16.07	11.97	0.23	7.47	9.72	2.92	0.52	0.28	3.10	100.32
20	ED79-307a	45.20	1.50	12.00	13.40	0.19	14.20	6.60	2.00	1.20	0.35	4.60	101.24
21	ED79-410	47.30	1.70	15.80	9.70	0.12	8.20	7.70	3.40	0.60	0.20	6.50	101.22
22	ED79-212	48.00	1.50	17.40	11.60	0.14	7.80	8.10	3.00	0.60	0.27	3.30	101.71
23	ED79-407	48.00	2.50	16.10	11.40	0.15	5.40	8.30	4.00	1.10	0.44	4.30	101.69
24	ED79-111	49.10	2.40	17.00	13.70	0.14	5.00	1.10	5.00	0.20	0.62	4.90	99.16
25	ED79-171	46.80	0.90	14.40	11.20	0.18	10.00	6.80	3.00	0.30	0.19	7.20	100.97
26*	ED79-200	50.27	2.37	16.81	8.38	0.10	3.76	4.06	7.14	0.18	0.74	5.79	99.61
27*	ED79-306	47.18	3.39	14.98	12.24	0.18	5.00	8.34	4.85	0.20	0.74	3.45	100.56
28	ED79-230	42.20	2.50	12.60	12.60	0.18	9.30	8.90	2.40	0.40	0.60	9.00	100.68
29	ED79-073	47.60	2.80	16.00	11.40	0.22	6.50	7.90	4.20	1.20	0.34	2.90	101.06
30*	ED79-256b	48.14	2.10	17.82	10.44	0.15	6.09	8.77	3.35	0.95	0.29	2.29	100.39
31	ED-79-279	47.30	3.40	15.20	11.20	0.17	4.30	8.90	4.20	2.10	0.69	2.10	99.56
32	16-W03-15	44.26	2.74	13.52	13.55	0.23	7.46	7.90	1.04	1.07	0.44	8.39	100.61

Table 1. (cont'd)

Map #	Sample #	Ba	Rb	Sr	Y	Zr	Nb	Th	Pb	Ga	Zn	Cu	Ni	V	Cr	Co	U	La	Nd
A*	ED79-255	151	109	345	23	223	43	4	10	22	79	34	148	359	388	59	<1	31	30
B	ED79-243		48	356	47	374	50		10		89								
C	ED79-213		33	375	33	179	23		11		78		18						
D	ED79-203		79	331	27	352	44		10		146		54						
E	ED79-150					143	17												
F	ED79-483b		5	319	28	141	16		7		83		120						
G*	ED79-458x	30	40	296	25	164	24	3	24	21	94	<4	48	257	209	45	<1	39	39
H	ED79-454a		20	408	34	180	31		8		85		29						
I	ED79-464b		11	326		157													
J*	ED79-109b	312	24	631	25	198	29	4	<3	21	87	7	15	257	212	43	<1	40	33
K*	ED79-448e	305	35	537	25	265	62	5	6	22	112	15	30	388	84	42	<1	37	39
L*	ED79-P16II	41	16	309	22	135	17	2	9	21	90	76	169	271	293	65	<1	14	11
M*	ED79-012a	232	44	547	23	289	71	7	4	22	80	6	118	339	166	48	<1	66	51
N	ED79-002j					287													
O*	ED79-002L	211	30	511	23	282	68	5	8	22	79	25	78	332	135	46	<1	57	53
P	ED79-002p		16	1004	32	326	36		0		83		20						
Q	ED79-002v		45	548	31	231	28		3		51		20						
R*	ED-79-018b	206		550		191	32			20	89		23	252	203				
S	ED79-044		14	371	26	151	18		6		69		301						
T	ED79-281				30	116	9												
1	ED79-399				52	264	23												
2	ED79-397		20	475	35	198	22												
3	ED79-438		1	286	49	295	42		81		658								
4*	ED79-361	60	16	266	24	150	17	4	<3	20	100	85	46	315	46	61	<1	12	16
5	ED79-363				34	146	16												
6*	ED79-139c	343	31	389	30	158	14	2	<3	21	87	41	27	223	125	48	<1	9	15
7	ED79-050a		3	680	29	184	21		2		71		65						
8	ED79-024		28	629	27	223	32		5		74		32						
9	ED79-025				32	188	26												
10a	ED79-008a		25	427	35	160	17												
10b*	ED79-008b	61	19	368	24	327	40	4	5	22	113	22	31	314	21	55	<1	34	33
11	ED79-006				32	223	27												
12	ED79-016a		13	444	22	144	16		4		78		31						
13	ED79-001		4	295	33	172	20		58		112		39						
14	ED79-106		14	242	35	104	11												
15	ED79-297c		38	390	28	164	22		5		75		28						
16a	ED79-493b					337	4												
16b	ED79-493c		6	423	26	224	23												
17	ED79-451		9	357	28	158	19		7		88		50						
18	ED79-3lg3		25	749	45	216	25												
19*	ED79-311	204	20	470	21	149	21	5	<3	21	96	<4	78	304	207	50	<1	19	26
20	ED79-307a		46	368	29	158	19												
21	ED79-410		22	480	27	132	13				67		111						
22	ED79-212		29	434	31	146													
23	ED79-407		40	540	33	230	16												
24	ED79-111					180	35												
25	ED79-171		15	516		131													
26*	ED79-200	158	12	344	29	344	100	6	19	23	91	10	3	255	5	36	<1	63	49
27*	ED79-306	43	12	572	28	249	52	4	<3	23	99	8	36	407	63	44	<1	34	41
28	ED79-230		42	875	27	241	33				100		152						

Table 1. (cont'd)

Map #	Sample #	Ba	Rb	Sr	Y	Zr	Nb	Th	Pb	Ga	Zn	Cu	Ni	V	Cr	Co	U	La	Nd
29	ED79-073		34	461	30	179	20												
30*	ED79-256b	528	33	871	23	225	32	5	10	20	83	15	50	282	215	47	<1	30	26
31	ED-79-279		55	1373		309													
32	16-W03-15	406	39	185	23	222	31	2	6	22	139	71	139	408	287	66	<1	37	38

[1]Re-analyzed samples (shown with astrix in first column) were done by X-ray Fluorescene at the Regional Geochemical Centre, Saint Mary's University, Halifax, Nova Scotia, using methods described by Slauenwhite (1999). The exception is sample ED-79-018b in which only the major package was done, due to limited sample size. Analytical error is generally less than 5% for major elements and 2-10% for trace elements. LOI is loss on ignition at 1000°C, nd = not determined.

Petrological Studies of Mafic Pegmatites in the Jurassic North Mountain Basalt, Nova Scotia: A Record of Extreme Fractionation in the Late-stage Evolution of Continental Tholeiites[1]

C. Baldwin[2], D. J. Kontak and J. Dostal[2]

The 201 Ma North Mountain Basalt (NMB) is a sequence of continental tholeiitic basalts erupted within a continental rift (Fundy Basin) that has been subdivided into lower, middle and upper flow units (LFU, MFU, UFU, respectively). Petrographically the basalts are medium- to fine-grained with ophitic textures and are variably vitrophyric (≤30%). The LFU is ≤190 m thick and massive in nature with well-developed colonnade and entablature fracture patterns. However, two exceptions are noted, namely the presence of a thin (≤1-3 m) amygdaloidal zone delineating the upper contact with the overlying MFU and rare, locally-developed pegmatite sheets in the upper part of the flow. This study focuses on two pegmatite localities, namely Mount Pleasant and Beamans Mountain, that outcrop near Digby. These areas were previously exploited for aggregate, the resultant excavations having provided exceptional exposure of the pegmatites sheets. The two areas were examined in detailed and mapped onto digitally-generated photos with subsequent sampling for petrography, and mineral and whole-rock geochemistry. We note the following textural and mineralogical features of the pegmatites, which are appropriately named given the presence of abundant, coarse (i.e., ≤10-15 cm) pyroxene crystals: (1) the contacts are welded with the host basalt and chilling is apparent; (2) the sheets are ≤3 m thick, but cm-scale lenses occur, and bifurcation is common; (3) internal zonation occurs, as defined by textural variation and different proportions of pyroxene, plagioclase and an aphanitic beige matrix; locally, pyroxenite occurs; (4) skeletal pyroxene is a prominent feature, often with comb and radial textures; (5) thin (≤1-2 cm), flat veins/dykes of aphanitic, beige felsite (i.e., granophyre in thin section) cut the pegmatites and locally they are miarolitic and globules of red-brown (rhyolitic ?) glass; (6) the pegmatites are dominated by coarse, normally zoned pyroxene that show prominent Fe enrichment with Fe/(Fe+Mg) to 0.8 and plagioclase (An_{40-70}) that may contain 0.5-1% wt.% FeO. Late phosphorus enrichment is manifested by abundant apatite euhedral in the granophyre and felsic glass.

Our observations indicate the pegmatites represent filling of flat to undulating dilatant zones within crystallized basalt by a mobilized, possibly filter-pressed, evolved melt generated via fractionation from a precursor basaltic magma. The heterogeneity nature of the pegmatite, locally Fe-rich pyroxenite, and presence of globules of rhyolite suggest that liquid immiscibility, documented elsewhere in the NMB, in addition to fractional crystallization, may have occurred within the basaltic magma.

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Significance of U-Pb Detrital Zircon Ages in Quartzite from peri-Gondwanan Terranes, New Brunswick and Nova Scotia, Canada[1]

S. M. Barr[2], D. W. Davis[3], S. Kamo[3] and C. E. White

Detrital ages have been determined for zircon grains from quartzite clasts in Neoproterozic conglomerate units in the Avalonian Mira and Caledonia terranes and from quartzite units in both Avalon terrane (Gamble Brook Formation) and the adjacent Brookville-Bras d'Or terrane (Green Head Group). These data are compared to published detrital zircon data from other sedimentary units in the Avalon and Brookville-Bras d'Or terranes, and from paragneissic units in the latter terrane. The aim of this study was to determine the source of the clasts and the general provenance of metasedimentary rocks in these terranes, data that could help to interpret whether the terranes were assembled by the Neoproterozoic or later during the Paleozoic.

Studied quartzite units in the Avalon terrane show no ages younger than about 1000 Ma, in contrast to stratigraphically younger conglomerate units, which contain a high proportion of detrital ages around 600 Ma, the peak of igneous activity in Avalon terrane. Quartzite from the Brookville terrane and quartzite clasts from the Mira and Caledonia (Avalon) terranes have no ages younger than about 1200 Ma. Detrital zircon ages from these units are concentrated in the range 2000-1200 Ma, and most samples also show some Late Archean ages. Paragneissic units in Brookville-Bras d'Or terrane show age peaks at ca. 700-650 Ma that slightly pre-date the main pulse of Avalon magmatism, and contain Mesoproterozoic zircon grains younger than those in the quartzite samples.

The broad range of Mesoproterozoic to Late Archean ages and general similarity of the age distributions suggest that Brookville-Bras d'Or terrane and Avalon terrane sensu stricto developed near the same or similar large continental landmasses, possibly over an extended period of time. On the other hand, the differences between the terranes, together with lithological and metamorphic contrasts, suggest that quartzite and paragneiss in the Brookville-Bras d'Or terrane are not directly related to each other or to sandstone/quartzite units in the Avalon terrane sensu stricto. Some components of their detrital age signatures point toward Amazonia as the associated landmass, but if so, Trans-Amazonian (2300-2070 Ma) rocks constituted only a very minor proportion of the source area. Baltica may be a more suitable source to explain the data. Quartzite clasts in the Mira and Caledonia terranes (Avalon terrane sensu stricto) show somewhat unique features, such as a concentration of ages around 2000 Ma and the presence of detrital metamorphic ziron at around 680 Ma. This metamorphic zircon may have been derived from a unit such as the Hammondville metamorphic suite in New Brunswick, which has been interpreted to represent the remains of a subduction complex in the Avalon terrane.

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U-Pb Ages of Detrital Zircon in Quartzite from Avalon and Adjacent Terranes, New Brunswick and Nova Scotia, Canada[1]

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To investigate the provenance of sedimentary units in Avalon and adjacent terranes, U-Pb ages have been determined for detrital zircon from quartzite clasts in Neoproterozoic conglomerate units in the Avalon terrane of Maritime Canada, and from quartzitic units in both Avalon terrane and adjacent Brookville-Bras d'Or terrane. These data are compared with published detrital zircon data from other units in Avalon and Brookville-Bras d'Or terranes, and from paragneissic units in the latter terrane.

Metasedimentary units in Avalon terrane show no ages younger than about 1000 Ma, in contrast to stratigraphically younger conglomerate units, which contain a high proportion of detrital ages around 600 Ma, the peak of igneous activity in Avalon terrane. Quartzite from the Brookville terrane and quartzite clasts from the Mira and Caledonia (Avalon) terranes show no ages younger than about 1200 Ma. Detrital zircon ages from these units are concentrated in the range 2000-1200 Ma, and most samples also show some late Archean ages. Paragneissic units in Brookville-Bras d'Or terrane show age peaks at ca. 700-650 Ma that pre-date the main pulse of Avalonian magmatism, and contain Mesoproterozoic zircon grains younger than those in the quartzite samples.

The broad range of ages and general similarity of the distributions suggest that Brookville-Bras d'Or terrane and Avalon terrane *sensu stricto* developed near similar large continental landmasses, possibly over an extended period of time. However, differences between them suggest that quartzite and paragneiss in the Brookville-Bras d'Or terrane are not directly related to each other or to sandstone/quartzite units in the Avalon terrane *sensu stricto*. Some components of their detrital age signatures point toward Amazonia as the associated landmass but, if so, Trans-Amazonian rocks formed only a very minor proportion of the provenance. Baltica may be a more suitable source to explain the data. Quartzite clasts in Avalon terrane *sensu stricto* show somewhat unique features such as a concentration of ages around 2000 Ma and the presence of metamorphic zircon at around 670 Ma. This zircon may have been derived from a unit such as the Hammondville Metamorphic Suite in southern New Brunswick, which has been interpreted to represent remains of an accretionary prism in Avalon.

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U/Pb, Re/Os and Ar/Ar dating of the South Mountain Batholith and its Mineral Deposits[1]

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The peraluminous South Mountain Batholith (SMB) of Nova Scotia ranges in composition from least differentiated granodiorite and monzogranite to most differentiated leucomonzogranite and leucogranite. The most evolved fractions host polymetallic (Sn, W, U, Mo, Cu, Zn, Ag, and Mn) mineral deposits. We have attempted to: (i) constrain the age of granite emplacement and its relationship to the ca. 410 Ma Acadian orogeny; (ii) determine the temporal relationship between the different phases of the SMB; and (iii) assess the temporal relationship between SMB emplacement and mineral deposits formation. Here we integrate new age data (U/Pb on zircon and monazite, Re/Os on molybdenite, and Ar/Ar on muscovite) with published Rb/Sr, U/Pb, and Ar/Ar ages to constrain the duration of both magmatic and hydrothermal activity.

Zircon and monazite U/Pb data provide the best estimate of magma emplacement, and the oldest concordant zircon from granodiorite is 380 ± 3 Ma. A leucomonzogranite from the Sn-Zn-Cu-Mo-Ag East Kemptville (EK) deposit has a discordant zircon age of 385 Ma, whereas an albitite from EK yields a monazite age of 306 ± 3 Ma. Muscovite Ar/Ar data provide information on cooling history through the muscovite closure temperature. Single-grain Ar/Ar laserprobe ages for samples from mineral occurrences of the New Ross area (NRA), northeastern SMB, range from 382 to 320 Ma. Plateau ages within this range previously obtained by the incremental heating analysis of bulk separates are now interpreted as mean ages of variably reset muscovite grains. Molybdenite Re/Os data provide an age of mineralization. Samples from two metallogenic areas of the SMB yield the following results: (i) 376 ± 3 Ma (pegmatite from EK) and (ii) 377 ± 3 Ma and 371 ± 3 Ma (aplite/pegmatite from the NRA).

These data, integrated with previous work, suggest that: (1) the age of emplacement for the SMB is ~ 380 Ma, confirming its status as a late-orogenic intrusion in the Meguma terrane; (2) the main phases of hydrothermal activity leading to polymetallic mineralization occurred in close temporal relationship to granite emplacement; and (3) episodic tectonic-thermal-hydrothermal events took place at ~370 Ma and ~300 Ma, partially resetting the Ar/Ar system.

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Communicating the Relevance of Earth Science with a Geological Highway Map[1]

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Making earth science relevant to various audiences including schools and decision makers is a major challenge. In many situations earth science information may not be appreciated for its value to society or worse, its existence may not be known. Keeping earth science relevant involves showing how it may be used personally and publically. The 'recreational use' of earth science information connects people with different backgrounds to earth science. When we make earth science 'fun' through such activities as rock, fossil and mineral collecting, field trips, and museum visits, we build interest and understanding in a broad base of the population. One of the vehicles for furthering this interest at a personal level is the use of specialized maps such as the *Geological Highway Map of Nova Scotia*. This map and others in use in North America invite people to become more involved with rocks, minerals, fossils and landforms. It relates the location of geological units, collecting sites, landforms and their connection to the underlying rock units, and outcrop locations to the highway system. Two editions of the map have already been published by the Atlantic Geoscience Society (AGS) and a third is due in the Spring of 2003. In the early 1990s the Government of Nova Scotia included the map in a four-part map publishing project. The combined sales of all editions have totaled more than 40,000 copies. The *Geological Highway Map of Nova Scotia* is used by the AGS in its annual EdGeo Workshops, funded in part by the Canadian Geoscience Council, for helping earth science teachers teach the Pan-Canadian science curriculum in Nova Scotia. The map is a companion to the AGS's much acclaimed book *The Last Billion Years*. University earth science classes and many senior high schools use the map as part of the course materials. Large numbers are purchased by residents and visitors to the province. This wide spread use contributes to a better understanding and appreciation of earth science. Interest and knowledge generated by collections, images and observations based on the map from Nova Scotia are transferable to other parts of North America. The map is a powerful tool in generating interest in earth science and thereby communicating the relevance of earth science.

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Chemical and Isotopic (Pb, Sr) Zonation in a Peraluminous Granite Pluton: Origin by Crystal-fluid Fractionation[1]

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The Davis Lake pluton (DLP, ~800 km^2) of southwestern Nova Scotia, Canada, part of the large peraluminous South Mountain batholith of ca. 380 Ma (U/Pb zircon, Ar/Ar mica), consists of granite and subordinate topaz-muscovite leucogranite that is host to greisen tin-base metal mineralization. A new Pb-Pb isochron age for leucogranite from the most evolved part of the DLP indicates a crystallization age of 378 ± 3.6 Ma, coincident with other radiometric ages in the area (Rb-Sr, Re-Os, Pb-Pb). The intrusion displays a compositional zonation defined by lead and strontium isotopic ratios, as well as some major elements (e.g., Si, F), incompatible trace elements (e.g., Li, Rb, Ta, U, Sn), and elemental ratios (e.g., K/Rb and Nb/Ta). The greisens and the leucogranites that host them are characterized by extreme radiogenic compositions for Pb and Sr, and their chemical-isotopic trends are extensions of the trends displayed by the less evolved granites. The granitoid magma underwent extensive fractional crystallization of feldspars, minor biotite and accessory minerals (monazite, apatite and zircon) in a compositionally zoned magma chamber that was subsequently accompanied by fluid fractionation during which time the internally-derived fluorine-rich fluids modified the Rb/Sr, U/Pb and Th/Pb ratios leading to distinct variations of $^{87}Sr/^{86}Sr$, $^{206}Pb/^{204}Pb$, $^{238}U/^{204}Pb$ and $^{232}Th/^{204}Pb$ isotopic ratios. These data document, therefore, the transition of a primitive magma through the stages of magmatic (i.e., crystal fractionation), orthomagmatic (i.e., crystal-fluid fractionation) and hydrothermal (i.e., fluid fractionation) that culminated in formation of a tin-base metal deposit. The Pb isotope data also constrain the source region for the DLP as being Avalonian basement which, by inference, must underlie much of the Meguma Terrane.

[1]*In* Contributions to Mineralogy and Petrology, v. 147, p. 74-90
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$^{40}Ar/^{39}Ar$ Age of the Jurassic North Mountain Basalt, Southwestern Nova Scotia[1]

D. J. Kontak, and D. A. Archibald[2]

Two whole-rock samples of the Jurassic North Mountain Basalt have been dated using the $^{40}Ar/^{39}Ar$ method. A single sample of fresh, medium-grained, holocrystalline basalt from the lower flow unit of this thick (i.e., 400 m) sequence gave coincident plateau and isochron correlation ages of 201 ± 2.5 Ma, in agreement with a zircon U-Pb age of 202 ± 1 Ma for this same flow unit. This $^{40}Ar/^{39}Ar$ age contrasts with earlier conventional K-Ar whole-rock ages of ca. 192 Ma for the North Mountain Basalt, which are similar to other K-Ar and Ar/Ar ages for correlative basalts of eastern North America. The second dated sample is a zeolite-bearing basalt from the middle flow unit of the North Mountain Basalt. This sample gave a discordant age spectrum with excess argon, but the isochron correlation age of 206 Ma, albeit with a large error (i.e., 56 Ma), is similar to that for the fresh sample. The data indicate that reliable whole rock $^{40}Ar/^{39}Ar$ ages for the basalts are attainable, but that fresh samples must be used. In light of this, it is suggested that the younger 192 Ma ages may reflect a widespread thermal event related to zeolite formation.

[1] *In* Atlantic Geology, 2003, v. 39, p. 47-53
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Re/Os Analysis of Arsenopyrite from Meguma Lode Gold Deposits: Implications for Timing of Gold Metallogeny and Age of Acadian Deformation in the Meguma Terrane, Nova Scotia[1]

D. J. Kontak, R. J. Horne, R. Morelli[2] and R. Creaser[2]

Meguma lode gold deposits (MLGD) occur within Cambro-Ordovician metaturbidites of the Meguma Group, which were deformed into upright, northeast-trending box and chevron-type folds during the Devonian Acadian Orogeny. The MLGD are dominated by quartz veins with associated carbonate and arsenopyrite and trace Fe, Pb and Zn sulphides. Geological mapping and structural analysis of several gold districts indicate that bedding concordant, discordant, en enchelon and saddle reef vein types dominate and that they can be related kinematically. In addition, the mutual cross-cutting relationships of all vein types suggest a similar time of emplacement, which is inferred to have been late in the folding history of the host rocks. This timing of vein emplacement is consistent with the following observations: (1) veins locally crosscut hornfels adjacent ca. 375 Ma granites (e.g., Mooseland and Beaver Dam districts); and (2) ca. 375 Ma $^{40}Ar/^{39}Ar$ plateaux ages for hydrothermal vein minerals (amphibole, biotite, muscovite) from several gold districts (n=7). In order to further constrain the timing of vein formation, we have undertaken Re/Os analyses of vein and wallrock arsenopyrite from three gold districts where the absence of hydrothermal vein minerals preclude dating by the $^{40}Ar/^{39}Ar$ method - The Ovens, Dufferin, and the Touquoy Zone (Moose River district). Whereas The Ovens and Dufferin are similar geologically (i.e., hinge area of anticlines) and contain all vein types typical of MLGD, the Touquoy Zone represents vein-free, disseminated style gold mineralization. The results of Re/Os analyses indicate ages of 408 ± 4 Ma for The Ovens and 381 ± 3 Ma for Dufferin and Touquoy. These data along with previous $^{40}Ar/^{39}Ar$ ages have implications for gold metallogeny and tectonism within the Meguma Terrane: (1) vein formation and, hence, gold mineralization is coincident with two widespread events within the Meguma Terrane, namely regional deformation and felsic plutonism; and (2) the timing of regional deformation is now constrained to ≥408 Ma, which contrasts with current estimates based on $^{40}Ar/^{39}Ar$ whole rock and mineral ages (i.e., ca. 400-390 Ma). The difference in time of deformation is considered to reflect the higher blocking temperature of the Re/Os chronometer in arsenopyrite compared to the K-Ar system in mica and clearly demonstrates the need for additional high-temperature chronology to better constrain the absolute timing of deformation and gold mineralization in the Meguma Terrane.

[1]Atlantic Geoscience Society Annual Meeting, January 2004, Moncton, New Brunswick; *in* Program and Abstracts
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The Brazil Lake Pegmatite, Southwestern Nova Scotia: Role of Sodium Metasomatism in an LCT-type Pegmatite of Magmatic Parentage[1]

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The Brazil Lake Pegmatite (BLP) occurs in metasedimentary and metavolcanic rocks of the Silurian White Rock Formation, southwestern Nova Scotia, and crystallized at 378 ± 1 Ma (concordant U/Pb tantalite age). The BLP occurs ca. 10 km west of the termination of the chemically evolved, peraluminous, F- and Li- rich Davis Lake Pluton (DLP), part of the 380 Ma South Mountain Batholith. The pegmatites form a NE-trending, steeply-dipping, en echelon dyke swarm ca. 700 m long with individual pegmatites <10-20 m width. Detailed mapping of the southern dykes revealed the following assemblages: (1) heterogeneous nucleation of coarse (1-2 m) Kfs and Spd crystals oriented perpendicular to the contact; (2) intergranular Qtz-Kfs-Ab-Ms-Spd between the coarse Kfs and Spd with mineral proportions varying considerably; and (3) a locally developed wall zone of fine-grained pegmatite with quartz enrichment. Secondary mineral growth is recorded by: (1) abundant exomorphic tourmaline in the wallrock quartzite and mafic volcanics, and replacing inclusions of volcanic rock near contacts; (2) silicification of the wall rock; (3) abundant, fine-grained sacchroidal-textured albite and euhedral cleavelandite replacing primary pegmatitic Kfs ($Or_{75}Ab_{25}$; K/Rb=20, K/Cs=450-1000); and (4) abundant muscovite (Rb=<5000 ppm, Li=330-1500 ppm) after Kfs. In addition to the major phases, accessory minerals, many of which are secondary and occur in albite-rich rock, include apatite (Mn- and F-rich types), Mn-rich garnet, triplite, beryl, topaz, Ta-Nb oxides, cassiterite, biotite, titanite, lithiophillite, fillowite, and amblygonite/montebrasite. Whole-rock analyses of pegmatite samples indicate positive correlations for P, Ca, Ta versus Na, which reflects metasomatic mobility of the elements. Our observations indicate that a primary assemblage of Kfs-Qtz-Spd-Ms was modified by interaction with a Na-rich, magmatic fluid that formed albite/cleavelandite - rich zones after primary Kfs with enrichment in Nb-Ta oxides and associated secondary Li-P phases. Liberation of K during Kfs destructive alteration was sequestered in secondary muscovite. Preliminary fluid inclusions measurements (T_h=200-300°C, 5-25 wt. % eq. NaCl) combined with the absence of petalite in the BLP constrains initial formation conditions to ca.550°C and 3-3.5 Kbars with subsequent PT evolution similar to that at the Tanco pegmatite. Initial ^{18}O isotopic analysis indicate: Qtz=8.4-10‰, Ms=7-7.8‰, Spd=6.2-7.1‰, Ab=8.5-8.8‰, Tur=6.8-8.0‰, Grt=9-11.1‰. These data indicate an initial magmatic system was contaminated by the country rock via fluid interaction as the system cooled. The BLP melt is considered to represent an evolved fractionate of the DLP found at depth or laterally from this site.

[1]Geological Association of Canada-Mineralogical Association of Canada, Annual Meeting, Brock University, St. Catharines, Ontario; *in* Abstracts with Programs

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Gold in the Meguma Terrane, Southern Nova Scotia: Is There a Continuum between Mesothermal Lode Gold and Intrusion-related Gold Systems?[1]

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The Meguma Terrane (MT) of southern Nova Scotia is dominated by two lithotectonic units, the Cambro-Ordovician Meguma Group metasedimentary rocks and 380 Ma peraluminous South Mountain Batholith and related intrusions. The Meguma Group consists of a lower, sandstone-dominated unit and an overlying siltstone dominated unit. These strata were folded (chevron and box fold styles) and metamorphosed (greenschist to amphibolite grade) during the Acadian Orogeny at ca. 410 Ma. Intrusive activity of 380-370 Ma was dominated by crust-derived peraluminous granites, but lesser amounts of spatially- and temporally-related mafic intrusions occur. Gold production from Meguma lode-gold deposits (MLGD) was from both concordant and discordant, quartz-carbonate-sulphide veins that formed relatively late in the folding history of the host rocks - a metamorphic origin is suggested for their origin. However, integration of past and recent observations with changing global concepts on gold metallogeny suggests that a reassessment of these deposits is warranted. In this regard, the following points are highlighted: (1) recent Re/Os dating of arsenopyrite from several MLGD indicates two vein-forming events at 408 and 380 Ma. These ages for vein formation are significant and coincide with regional deformation and plutonism in the MT; (2) widespread occurrence of MLGD throughout the MT irrespective of metamorphic grade, stratigraphic position, and proximity to intrusions; (3) spatial association of some vein mineralogy (e.g., garnet, amphibole, tourmaline, calcic plagioclase) in MLGD proximal to intrusions (e.g., Newhouse, 1936); (4) elemental enrichment of some MLGD veins in a suite typical of intrusion-related gold deposits (i.e., Bi, Te, Mo, Sb), and (5) arsenopyrite-bearing albitites, quartz veins, and quartz-muscovite-tourmaline-sulphide greisen swarms (e.g., 260 m long by 120 m wide) that are hosted by 380 Ma, reduced, peraluminous granites. These systems are variably enriched in Au (to 2 g/t) and have a metal association (i.e., Bi, Co, W, Sb) typical of intrusion-related gold systems. The foregoing observations are interpreted to indicate that those MLGD of ca. 380 Ma may in fact form a continuum with intrusion-related gold mineralization hosted by intrusions of similar age. Thus, within the MT two distinct gold-mineralizing events are suggested, one at 408 Ma related to regional deformation accompanying accretion of the MT to Avalonia and a second at 380 Ma that is related to emplacement of crust-derived granites. The general similarities of all the MLGD indicates the non-uniqueness of the deposits and suggests, instead, that there may be a continuum between intrusion-related and mesothermal type vein mineralization.

[1]Geological Association of Canada-Mineralogical Association of Canada, Annual Meeting, Brock University, St. Catharines, Ontario; *in* Abstracts with Programs

Petrology and Tectonic Setting of the Carboniferous Wedgeport Pluton, Southwestern Nova Scotia[1]

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The Wedgeport Pluton, located southeast of Yarmouth in southwestern Nova Scotia, intruded Cambrian metasedimentry rocks of the Goldenville Formation. The pluton is of particular interest because of its previously reported U-Pb age of ca. 316 Ma, which suggests that it may be the youngest granitoid pluton in the Meguma terrane. Also, east-trending fractures and shear zones in the pluton typically contain tin mineralization, and hence the pluton has been a focus for mineral exploration. Recent 1:10 000-scale bedrock mapping related to the Southwest Nova Mapping Project of the Nova Scotia Department of Natural Resources better defined contact relations and extent of the pluton. This honours thesis project is a follow-up study to better document petrography, mineral chemistry, and chemical composition of the pluton, and hence interpret its magmatic affinity and tectonic setting.

The Wedgeport Pluton consists mainly of medium- to coarse-grained equigranular monzogranite. Major minerals are quartz, plagioclase (albite-oligoclase composition), perthitic microcline, and Fe-rich biotite, with variably abundant garnet (Mn-rich grossular-almandine), titanite, zircon, magnetite, and epidote. Enclaves of biotite-rich granodiorite and coarse-grained granitic porphyry occur locally, as well as convolute compositional banding possibly related to magmatic flow near contacts with the country rock. Aplitic, pegmatitic, and mafic dykes are present locally. A narrow contact metamorphic aureole of garnet-bearing hornfels occurs on the exposed western margin of the pluton; the location of the eastern margin of the pluton is inferred by the presence of small granitic dykes, presumably related to the pluton, in the Goldenville Formation.

Eighteen representative samples from the granite vary in SiO_2 content between about 73 and over 77%. No systematic variation is apparent in CaO, Na_2O, or K_2O content, but TiO_2, Al_2O_3, Fe_2O_3, and P_2O_5 decrease with increasing SiO_2. Trace element data suggest that the pluton is a within-plate A-type granite, with elevated Zr, Nb, Y, and Rb contents. Nb, Y, and Ga ratio indicates derivation from melting of continental crust. Variations in Sr, Ba, and Rb show features typical of specialized granite.

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Re-Os Arsenopyrite Geochronology of Quartz Veining and Au Mineralization, Meguma Terrane, Nova Scotia, Canada[1]

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The absolute timing of quartz veining and related Au mineralization in the turbidite dominated Meguma Terrane, Canada, is presently constrained by mica Ar-Ar age data. These dates from bedding-parallel, bedding-discordant, or saddle-reef quartz veins suggests that all vein types (and associated Au) were formed late in the deformational history of the Meguma Terrane at ~ 370-380 Ma, and that all deposits are of similar age regardless of location. To further constrain the origin of these *auriferous quartz veins*, we have determined Re-Os ages for arsenopyrite (asp), an abundant vein mineral having a cogenetic relationship with gold. Meguma asp contains only ~ 1-10 ppb Re but shows very low common Os and the Os is thus highly radiogenic and amenable for Re-Os dating. Re-Os ages were calculated by either an isochron approach using multiple samples from one vein, or as single-mineral model ages if the abundance of common Os was zero. Arsenopyrite from a bedding-parallel quartz vein forming the leg of a saddle vein at The Ovens in the SW Meguma Terrane yields an isochron age of 408 ± 4.5 Ma (2). Bedding-discordant quartz veins here contain asp having zero common Os and a model age of 407 ± 2 Ma. In the NE Meguma Terrane, asp from saddle-reefs at Dufferin yields an isochron age of 381 ± 3.3 Ma. One asp sample here also has zero common Os and gives a model age of 381 ± 2 Ma (2). The Re-Os asp dates show that at The Ovens, bedding-parallel and bedding-discordant veins are coeval. However, the ~ 408 Ma Re-Os age is significantly older than Ar-Ar mica from this locality (376 Ma). Thus, the mica either formed at a younger time relative to the veins, or potentially it is coeval with veining and has been thermally reset. At present there are no Ar-Ar ages for vein mica from Dufferin. At both Dufferin and The Ovens, structural analysis indicates veining occurred late in the deformational history, but the Re-Os asp dates indicate either a diachroneity of deformation across the Meguma Terrane, or the occurrence of a separate, younger mineralizing event (i.e., fold reactivation event) for saddle-reef ore at Dufferin. In addition, The Ovens asp data provide a minimum estimate of timing for Acadian deformation of 406 Ma. These results confirm that the Re-Os asp geochronometer is a useful tool for evaluating the timing of asp-bearing Au deposits.

[1]Geological Society of America Annual Meeting, October 2003; *in* Abstracts with Programs, v. 35
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Acadian Metamorphism with an Alleghanian Overprint: White Rock Formation, Yarmouth Area, Southwestern Nova Scotia[1]

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Acadian orogenesis in southwestern Nova Scotia resulted in metamorphism of Cambrian-Silurian units and the development of upright, NE-trending folds (F1) with axial-planar cleavage (S1). The White Rock Formation (WRF), comprising Silurian metasedimentary and metavolcanic rocks, crops out in a regional-scale syncline. The WRF is underlain by the slaty Halifax Formation (HF) and older turbiditic Goldenville Formation (GF), which together comprise the Cambrian-Ordovican Meguma Group.

Peak metamorphic porphyroblasts of staurolite, andalusite, garnet, plagioclase, chloritoid and biotite are largely post-kinematic with respect to the axial-planar slaty/phyllitic foliation (S1). Their distribution reveals substantial strike-normal differences in grade. Chlorite- and biotite-zone assemblages in the GF and central part of the WRF contrast markedly with staurolite ± andalusite-bearing assemblages developed in the lower WRF and HF. Mineral assemblages and thermobarometric data from amphibolite facies pelites and interlayered metabasites suggest moderate temperatures (550-600°C) and low to moderate pressures (4-6 kb) during peak metamorphism.

Elsewhere in the Meguma terrane, muscovite defining the regional slaty cleavage (S1) has yielded ca. 390 Ma $^{40}Ar/^{39}Ar$ ages. This cleavage and the M1 regional metamorphic assemblages are locally overprinted in the contact aureoles of ca. 375 Ma granitic plutons. Peak metamorphism is therefore inferred to be of Acadian age, although Acadian ages have been difficult to obtain from the WRF owing to the effects of later deformation and metamorphism.

Peak metamorphic assemblages (M1) and associated structures (D1) are strongly overprinted within broad (5 km), strike-parallel D2 shear zones that encompass the lower parts of the WRF and subjacent HF. The shear zones coincide with areas of highest Acadian metamorphic grade, suggesting that the present distribution of M1 isograds is controlled by these D2 structures. Synkinematic (D2) neoblastic chloritoid and albite growth accompanied pervasive matrix recrystallisation, boudinage, and retrogression of peak metamorphic porphyroblasts. Ubiquitous ca. 325 Ma $^{40}Ar/^{39}Ar$ muscovite ages suggest that D2 deformation and metamorphism represent the effects of the Alleghanian orogeny in SW Nova Scotia.

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The Appalachian Glacier Complex

R. R. Stea

Large, local ice centres, collectively termed the Appalachian Glacier Complex, developed in Maritime Canada during the Wisconsinan glaciation, effectively barring Laurentide ice from the region. These ice centres shifted in time and space, producing palimpsest glacial landforms including cross-striated bedrock outcrops and lobate drumlins. Based on provenance, offshore glacial sediments were correlated to their terrestrial counterparts, establishing crucial links between ice flow patterns on land and ice margins offshore. From these empirical data five major flow patterns or "phases" were defined along with their offshore margins. During the Caledonia Phase in the Early to Middle Wisconsinan, eastward to southeastward-flowing ice from Appalachian upland sources crossed Nova Scotia and extended to the continental shelf edge where a calving margin was established. Submarine mass-wasting at this margin produced wedge-shaped bodies of diamicton that interfingered with glaciomarine sediments. The Caledonia Phase glacier retreated during the Middle Wisconsinan to the inner Scotian Shelf. During the Escuminac Phase in the Late Wisconsinan (22-19 ^{14}C ka) an ice centre formed over the Magdalen Shelf (Escuminac Ice Centre) and transported large quantities of local redbed material southward to the outer shelf/slope margin. Just after 18 ^{14}C ka, the Escuminac Phase glacier configuration was re-organized by northward-flowing ice streams into marine channels bordering the Magdalen Shelf and an ice stream draining the Bay of Fundy into a divide over Nova Scotia (Scotian Ice Divide- Scotian Phase). The Scotian Phase glacier margin offshore is marked by the Scotian Shelf End Moraine Complex dated between 17 and 14 ^{14}C ka. Between 13.5 and 12.0 ^{14}C ka the Scotian Ice Divide segmented into local terrestrial ice centres (Chignecto Phase) as a calving bay developed in the Bay of Fundy. These local centres advanced and retreated, responding to mass balance changes during a time of rapidly changing northern hemisphere climates. Responding to increasing climatic warming after 12 ^{14}C ka, the Chignecto Phase glaciers dissipated and their margins retreated landward. Isolated marine and terrestrial remnants of the Chignecto Phase glaciers re-advanced significantly during the Collins Pond Phase (Younger Dryas) just after 10.8 ^{14}C ka.

Ice Stream Tills, Ice Divide Tills, and Reworked Tills in Nova Scotia, Canada

R. R. Stea and P. W. Finck

In Maritime Canada a succession of local ice caps called the Appalachian Ice Complex developed during the Wisconsinan glaciation. These glaciers were drained by ice streams into the submarine channels bordering the region. The migration of these ice centres throughout the Wisconsinan produced areas with widely differing flow patterns, landform assemblages and deposits. Early regional phases of ice flow were characterized by wide, rapidly flowing ice streams that formed thick allochthonous, silty tills in some areas restricted to drumlin fields. In later phases, ice divides shifted over coastal upland areas underlain by metamorphic and igneous rocks, forming stony, locally-derived tills. Terrain zones characterized by distinct transport histories and depositional sequences were produced by the interplay and migration of ice divides in the region. The interaction of newly-formed ice divides and previously deposited tills produced hybrid tills through two reworking processes: inheritance and overprinting. Inheritance is the incorporation of till components and/or fabric into a younger till by erosion and entrainment of material from an older till. Overprinting is the injection or imprint of matrix, clasts or fabric on older tills by overriding ice. Glacial dispersal of rocks, minerals and trace elements in this complex glaciated terrain is largely controlled by the location and persistence of former ice divides. Simple unidirectional dispersal trains are preserved in relict terrains under areas of former ice divides and in "by-passed" terrains such as ice rises between ice streams. In ice marginal areas and along ice stream paths (drumlin fields), reworking processes were enhanced, resulting in complex dispersal fans by smearing and widening of previously formed trains and fans. These dispersal fans can be modeled by vector addition of the discrete flow events within each dispersal zone.

Younger Dryas Glacierization in the Gulf of St. Lawrence, Canada

R. R. Stea, R. J. Mott[1], D. I. Godfrey-Smith[2] and J. L. Fastook[3]

In the summer of 1999, the Maritimes and Northeast Pipeline Company excavated a 3 m deep ditch across northern Nova Scotia to host the Sable Island gas pipeline. A late-glacial paleosol with preserved A-horizon was buried under 2-10 m of surface till over a wide area of the pipeline route. The A horizon peaty layer is only a few cm thick, and consists mainly of herbaceous plant material with a few large wood fragments yielding conventional radiocarbon ages of 10.9 ka and 10.8 ka. The paleosol is relatively flat lying under a gently undulating, fluted glacial topography. Fabric analysis in the reddish surface till, indicate a strong trend parallel to regional glacial lineations. Glacial flow lines indicated by fabric and fluting of the YD surface till sheet in northern Nova Scotia and ice marginal deposits imply an ice cap centred around Prince Edward Island. The YD glacier margin is marked by ice-marginal lakes north of the Cobequid Highlands of Nova Scotia and a series of glacial lakes dammed against the highland-rimmed west coast of Cape Breton Island. Paleosol sites and almost 20 other buried wood and peat organic horizons throughout Nova Scotia allow an accurate reconstruction of glacier limits and provide a robust radiocarbon chronology of deglaciation.

The University of Maine Ice Sheet Model (UMISM) was used to test the hypothesis of development of a glacier in the Gulf of St. Lawrence. The UMSIM model produced a strikingly similar configuration to the empirical glaciation model using a slightly modified modern climate and the GRIP ice core temperature proxy record scaled by 1.5. The Gulf of St. Lawrence region may have also been the locus of increased snowfall during the Younger Dryas as a result of deflection of the jet stream by semi-permanent high pressure cells over the Laurentide ice sheet and a sea-ice covered North Atlantic Ocean. Rapid glacier development in Maritime Canada on both shelf and highland areas during the Younger Dryas may mirror the glacierization in Appalachian regions south of the Laurentide Ice Sheet during MIS 4.

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Late-glacial Ice Advances in Maritime Canada

R. R. Stea, R. J. Mott[1], J. Gosse[2] and J. Fastook[3]

Maritime Canada can be considered a canary in the coal mine of climate change, especially at the end of the last glaciation, when it was situated between the Laurentide Ice Sheet (LIS) and the North Atlantic. Three ice advance events at the end of the last (Wisconsinan) glaciation are recorded in the stratigraphy of this region. Starting about 17.0 ka (all calibrated ages) there was a major period of ice retreat, followed by readvances of several local ice caps with terrestrial and marine margins. The oldest, termed the Chignecto Phase is dated between 15.2 and 16.0 ka and is roughly correlative with the Port Huron event of the mid-continent and the "oldest" Dryas in Europe. After this there is evidence for a short-lived re-advance dated about 13.5 and 14.0 ka (Shulie Lake Phase) correlative with the "older" Dryas.

The next major event was the advance of remnant glaciers during the Younger Dryas (YD) termed the Collins Pond Phase (~ 13 ka). A paleosol formed during the warming phase is preserved under surface tills, best exposed during an excavation for the Sable Island Gas Pipeline in 1999. The YD glacier margin is marked by ice-marginal lakes north of the Cobequid Highlands of Nova Scotia, and a series of glacial lakes dammed against the highland-rimmed west coast of Cape Breton Island. A 30-40 km re-advance of an ice cap centred around Prince Edward Island in the Gulf of St. Lawrence is indicated. These paleosol sites and 20 other buried wood and peat organic horizons throughout Nova Scotia allow an accurate reconstruction of YD glacier limits and provide a robust radiocarbon chronology of deglaciation.

The University of Maine Ice Sheet Model (UMISM) was used to analyze the conditions necessary for a field-based conceptual model of paleo-ice dynamics in the Gulf of St. Lawrence. The model produced a strikingly similar configuration to the empirical glaciation model of the Collins Pond Phase using a slightly modified modern climate and the GRIP ice core temperature proxy record scaled by 1.5. The Gulf of St. Lawrence region may have been the locus of increased snowfall and amplified cooling during the Younger Dryas, and during previous cold periods, as a result of deflection of the jet stream by semi-permanent high pressure cells over the LIS and sea-ice covered North Atlantic ocean.

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Stratigraphy, Structure, and $^{40}Ar/^{39}Ar$ Geochronology in the Lochaber-Mulgrave area, Nova Scotia[1]

P. J. Ténière[2], S. M. Barr[2], C. E. White and P. H. Reynolds[3]

The Lochaber-Mulgrave area of northern mainland Nova Scotia is underlain by rocks of the Early Carboniferous Horton Group, in faulted contact with Devonian and Silurian rocks to the south and west and younger Carboniferous rocks to the north and east. On the basis of lithology and sedimentary characteristics, the Horton Group is divided into four formations: Clam Harbour River, Tracadie Road, Caledonia Mills, and Steep Creek. These formations have a total thickness of at least 4000 m, and were deposited in varied braided fluvial and shallow to deep lacustrine environments. Sparse paleontological data from macrofossils and spores indicates an age of Famennian to late Tournaisian. Compared to the Horton Group in other areas of Nova Scotia, the rocks in the Lochaber-Mulgrave area appear to be somewhat older, exhibit higher thermal maturity indicating deeper burial, and are more deformed and metamorphosed, especially in the southern part of the area near the Roman Valley Fault. Detrital muscovite yielded $^{40}Ar/^{39}Ar$ ages of ca. 500 Ma, for which no source is apparent in either of the now-adjacent Avalon or Meguma terranes.

Based on petrographic studies, the rocks have undergone low-grade regional metamorphism with the development of slaty cleavage defined by new muscovite growth with a strongly preferred optical orientation. Whole-rock $^{40}Ar/^{39}Ar$ dating of muscovite-rich slate indicates that new muscovite growth occurred at ca. 350-340 Ma. These data require that the sedimentary rocks underwent extremely rapid burial, deformation, and cooling through the argon retention temperature in muscovite by ca. 350-340 Ma. A possible explanation is overthrusting of the Horton Group from the south by Devonian rocks of the Guysborough block, as a result of transpression at a restraining bend along the Chedabucto-Roman Valley fault system during juxtaposition of the Avalon and Meguma terranes. Further evidence of an overthrusting event is evident to the northeast in Cape Breton Island where equivalent units in the L'Ardoise block display overturned sequences with recumbent folds and near-horizontal cleavage. Uplift and subsequent deformation that also involved younger units in the region were probably the result of on-going movement on the terrane-bounding fault system.

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[1]Presentation at the Northeastern Section, Geological Society of America 38th Annual Meeting, March 27-29, 2003; *in* Geological Society of America, 2003 Abstracts with Programs, v. 34, p. 28

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Basement Blocks in Southwestern Cape Breton Island and Adjacent Mainland Nova Scotia, Canada, and their Relationship to the Avalon Terrane[1]

C. E. White, S. M. Barr[2], J. W. F Ketchum[3] and P. H. Reynolds[4]

Metamorphic and igneous "basement" rocks are exposed in the Creignish Hills, North Mountain, Sporting Mountain, Cape Porcupine, and Petit-de-Grat areas in southwestern Cape Breton Island and adjacent mainland Nova Scotia. The Creignish Hills and North Mountain blocks consist of low-grade metasedimentary and metavolcanic rocks (Blues Brook and Malagawatch formations), low-pressure amphibolite-facies gneiss and migmatite (Skye Mountain gneiss and Lime Hill gneissic complexes), and ca. 555 Ma dioritic to granitic plutons with calc-alkalic, continental-margin arc affinity. These rocks represent the southernmost exposed part of the peri-Gondwanan but non-Avalonian Bras d'Or terrane.

The Sporting Mountain block consists of volcanic and sedimentary rocks intruded by the granodioritic Sporting Mountain Pluton. Lithological similarities and a U-Pb zircon crystallization age of 619 +/- 2 Ma for a rhyolitic flow confirms that Sporting Mountain block is part of the Mira (= Avalon) terrane of southeastern Cape Breton Island.

The Cape Porcupine block on mainland Nova Scotia consists of relatively undeformed ca. 610 Ma granite and syenite thrust over mylonitic metasiltstone which yielded $^{40}Ar/^{39}Ar$ whole-rock ages of ca. 365 Ma. The metasiltstone is in faulted contact with mylonitic metavolcanic and granitoid rocks, the latter with an Early Ordovician U-Pb zircon crystallization age of ca. 480 Ma. The relationship of the Cape Porcupine block to other basement blocks is uncertain.

The Petit-de-Grat block consists of slivers of varied "basement" rocks, including mylonitic granite, amphibolite, and sillimanite-garnet schist, as well as conglomerate and minor basalt intruded by granite, all in faulted contact with younger Carboniferous sedimentary rocks. A U-Pb zircon age of ca. 373 Ma for the undeformed granite, and the presence of a contact aureole in adjacent conglomerate, are consistent with the interpretation that the conglomerate and basalt are part of the mid-Devonian Guysborough Group of mainland Nova Scotia. The similarity of the metamorphic rocks to basement exposures elsewhere associated with the Avalon - Meguma terrane boundary suggests that the Petit-de-Grat area may be part of the Meguma terrane.

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[1]Presentation at the Northeastern Section, Geological Society of America 38th Annual Meeting, March 27-29, 2003; *in* Geological Society of America, 2003 Abstracts with Programs, v. 34, p. 17-18

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A New Perspective on Stratigraphy, Deformation, and Metamorphism in the Southwestern Meguma Terrane, Nova Scotia[1]

C. E. White and R. J. Horne

Detailed mapping in the Meguma terrane from Digby to Shelburne was initiated in 1998 by the Nova Scotia Department of Natural Resources to produce updated 1:50 000 scale geological maps of the area. The new maps better define the distribution of, and show internal stratigraphic subdivisions in, the Goldenville and Halifax formations of the Meguma Group. Newly discovered occurrences of Early Tremadocian graptolite fossils near the top of the Halifax Formation confirm that the Meguma Group is mainly Cambrian in age, with the Halifax Formation extending into the Early Ordovician.

The White Rock Formation overlies the Meguma Group but original contact relations are controversial. Late Silurian fossil occurrences near the top of the formation and U-Pb ages of ca. 440 Ma for volcanic rocks near the base indicate that the White Rock Formation is dominantly Silurian. The ca. 50 million-year difference in age between the upper part of the Halifax Formation and the lower part of the White Rock Formation suggests an originally unconformable relationship.

Mid-Devonian regional metamorphism was at greenschist facies for most of the area, but reached amphibolite facies in the White Rock Formation in the Yarmouth area and in the Meguma Group in the Shelburne area. Muscovite and whole-rock $^{40}Ar/^{39}Ar$ data from the Digby area indicate that metamorphism occurred at ca. 400 Ma, similar to results reported from the eastern part of the Meguma terrane. However, based on structural studies and published age data, high-grade regional metamorphism in the Shelburne area was younger (ca. 373 Ma). The age of high-grade metamorphism in the White Rock Formation is not yet well constrained.

Major shear zones have been mapped throughout the area. The most significant occur along the margins of the White Rock Formation in the Yarmouth area and continue to the Digby area. These shear zones locally juxtapose staurolite schist in the White Rock Formation against chlorite and biotite-bearing slate of the Halifax Formation. The most southeasterly shear zone juxtaposed the Meguma Group and White Rock Formation with abundant mafic sills on the north against the Meguma Group with contrasting internal stratigraphy and no White Rock Formation or mafic sills to the south. $^{40}Ar/^{39}Ar$ muscovite ages of 335-320 Ma suggest that these shear zones are Alleghanian.

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[1]Presentation at the Northeastern Section, Geological Society of America 38th Annual Meeting, March 27-29, 2003; *in* Geological Society of America, 2003 Abstracts with Programs, v. 34, p. 13

Appendix 1
Mining Industry Activity in Nova Scotia, 2002

Mining Industry Exploration, Development, Capital and Repair Expenditures

Investment by the mining industry in Nova Scotia is monitored by means of annual surveys of all mining companies having operations or activity in the province. The Nova Scotia Department of Natural Resources (DNR), along with Natural Resources Canada (Minerals and Metals Sector - Minerals and Mining Statistics Division), and Statistics Canada (Investment and Capital Stock Division), carries out the surveys. The Mineral Management Division of DNR actively participates in the Annual Survey of Canadian Mineral Exploration Expenditures and the Annual Survey on Exploration, Development, Capital and Repair Expenditures.

Preliminary figures indicate mineral exploration expenditures in 2002 totalled $3.45 million, up 8.4% from 2001 with an additional $5.63 million spent on mine complex development (Table 1.1). Diamond-drilling was down appreciably to 3 500 metres. Capital expenditures at existing mines were much higher in 2002 totalling nearly $17.0 million, while repair and maintenance expenditures were also up slightly to $18.1 million. Expenditures at aggregate producers are not included in Table 1.1.

Mining Leases

There was one new Mining Lease issued in the province during the year. MacLeod Resources Limited was issued a Mining Lease for its marble property at River Denys, Inverness County.

Mining Permits

The department also issued a new Mining Permit to MacLeod Resources Limited for its marble property at River Denys, Inverness County, during the year.

Production Information from Mines, Quarries and Other Operations

In 2002, the estimated value of Nova Scotia's mineral production, including secondary mineral processing, totalled $269 million (Fig. 1.1), significantly lower than the total of $316 million in

Table 1.1. Mining industry expenditures in 2001 and 2002.

	2001	2002[1]
Mineral Exploration Expenditures[2] (field plus overhead)	**$3,177,805**	**3,446,198**
Exploration diamond-drilling[2]	**5 100 m**	**3 500 m**
Exploration drilling - other	**N/A**	**N/A**
Mine Complex Development Expenditures (field plus overhead)	**$7,945,857**	**$5,627,259**
Capital and Repair Expenditures at Mining Establishments		
Capital Expenditures	**$8,907,710**	**$16,986,263**
Repair and Maintenance Expenditures	**$16,767,531**	**$18,118,072**

[1]preliminary
[2]includes deposit appraisal

Appendix 1 2004: *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 139-152.

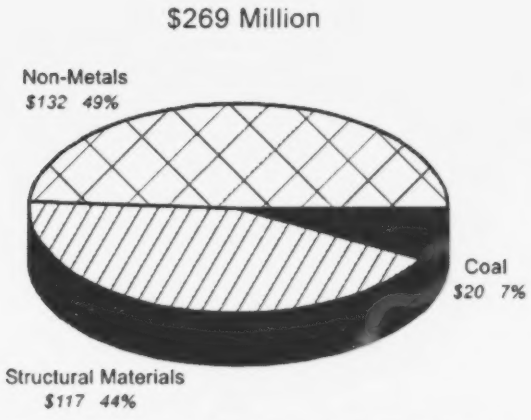


Figure 1.1. Value of mineral production, in millions of dollars and per cent, by commodity group.

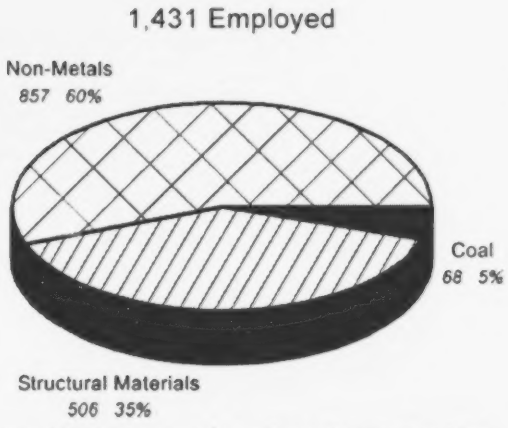


Figure 1.2. Employment, in numbers of persons and per cent, by mineral commodity group.

2001 due mainly to reduced coal production. The production value of most other commodities increased during 2002. Employment in Nova Scotia's mineral industry totalled 1,431 persons (Fig. 1.2), a dramatic 28% decrease from the previous year, mainly due to the shutdown of underground coal mining in 2001. As well, there was reduced employment in the province's surface coal and salt mining operations in 2002.

There were no gold mines operating in the province in 2002 following the suspension of operations at the Dufferin Mine in Port Dufferin in late 2001.

Nova Scotia's 2002 gypsum production was 6.96 million tonnes shipped. This represents a 2 % increase over 2001 gypsum production. Gypsum is supplied mainly to wallboard plants along the U.S. Eastern Seaboard and central Canada. Nova Scotia is Canada's largest gypsum producer, accounting for more than 80% of the country's total production.

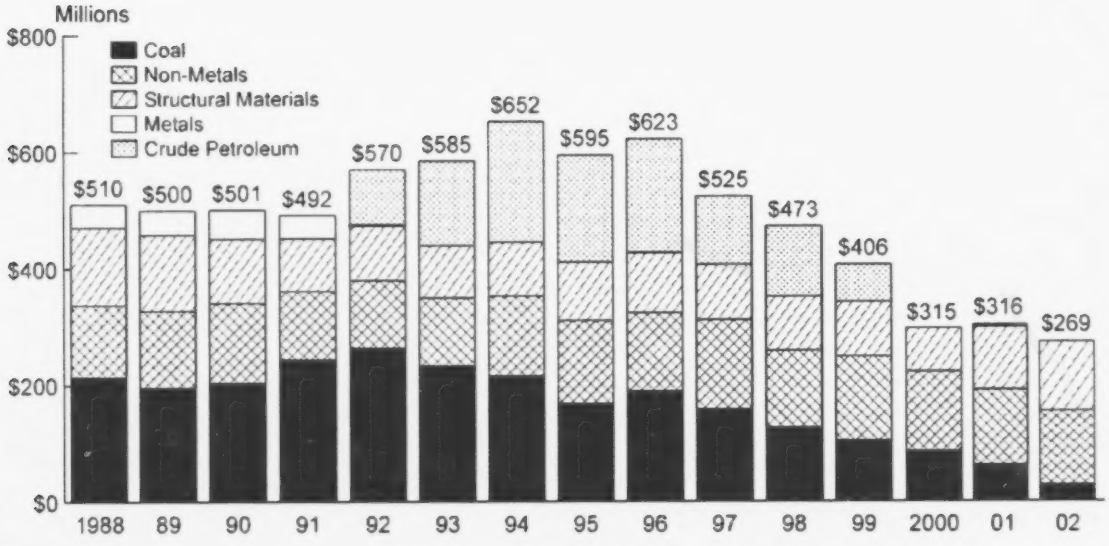
Nova Scotia's 2002 salt production decreased approximately 14% from 2001 to 952 000 tonnes.

Coal production was down sharply in 2002, to 374 000 tonnes. This production level reflected the closure of the Cape Breton Development Corporation's Prince Mine in Point Aconi, which closed in late 2001. The mine closure marked the end of a long continuous history of underground coal mining in Nova Scotia reaching back to the early 1700s, and the end to coal mining operations by the Cape Breton Development Corporation.

Portland cement/clinker production increased 4% in 2002 to over 303 000 tonnes.

Overall, aggregate (crushed stone, sand and gravel) production increased approximately 12% from 2001 to 13.2 million tonnes. Crushed stone production was down 4% while sand and gravel production increased 60%. Peat moss production was higher in 2002 at over 5 000 tonnes.

In the years prior to 2000, the value of petroleum production was included in the overall value of Nova Scotia's mineral production. However, there has been no production of crude oil since 1999 (Fig. 1.3), and the production of offshore natural gas is not included in this appendix. The appendix covers non-petroleum sectors of the mineral industry (Table 1.2), providing a description of each mine site. Tables 1.3 to 1.5 provide more detailed information on the production of different commodities. Site locations are shown on the accompanying maps, Figures 1.4 and 1.5. Production data are for the calendar year 1 January 2002 to 31 December 2002.



Includes secondary mineral processing where applicable

Figure 1.3. Historical trend in the value of mineral production in Nova Scotia, 1988-2002.

Metal and Gold Mines

Metal Mines

There were no producing metal mines in the province in 2002.

Gold Mines

There were no producing gold mines in the province in 2002.

Coal Mining Operations

During 2002, there were four active surface coal mines and a coal recovery project operating in the province. The use of innovative highwall mining technologies continued at specific surface mines that would normally have reached economic stripping limits. There were no producing underground coal mines in the province in 2002. Production information is summarized in Table 1.3. The summaries below provide details of the coal mines operating in Nova Scotia.

Surface Coal Mines

PIONEER COAL LIMITED

Manager: C. Chisholm
Address: PO. Box 1328
Antigonish, NS B2G 2L7
Production: 246,801 tons (223 897 tonnes) of coal
Employees: 23

Pioneer Coal mined coal from two steeply dipping seams at the Stellarton surface mine, Pictou County. The company has been mining on the Foord Seam since 1996 and began mining on the Cage Seam in 2001. The Foord Seam is approximately 12 metres thick and the Cage Seam approximately 5 metres thick.

In 2001, both conventional surface mining and highwall mining were used at Stellarton. However, in 2002 all production came from conventional surface mining, primarily from the Cage Seam. No blasting is used at the Stellarton mine. The coal and overlying rock material are excavated using hydraulic excavators, conveyors and off-road haul

Table 1.2. Summary of Nova Scotia mineral production, 2001 and 2002.

DESCRIPTION	2001 VALUE[1] ($ thousands)	2001 EMPLOYMENT*	2002 VALUE[1] ($ thousands)	2002 EMPLOYMENT*
METALS				
Gold	3,088	33	0	
Total metals	3,088	33	0	0
INDUSTRIAL MINERALS				
(Non-Metals)				
Anhydrite	***		1,073	
Barite	***		***	
Gypsum	75,466		80,037	
Limestone[2] and Dolomite	5,030		3,894	
Peat	***		713	
Salt**	***		43,021	
Silica	***		***	
Total Non-Metals	135,618	894	132,145	857
(Structural Materials)				
Dimension Stone	***		***	
Cement**	***		***	
Clay Products**	***		***	
Crushed Stone	58,811		56,740	
Sand & Gravel	14,096		20,609	
Total Structural Materials	112,430	473	116,787	506
Total Industrial Minerals	248,048	1,367	248,932	1,363
FUELS				
Coal	65,000	588	20,000	68
TOTAL MINERAL PRODUCTION	316,136	1,988	268,932	1,431
CHANGE FROM PREVIOUS YEAR	+0.4%	-7%	-15%	-28%

[1]Estimated from Department of Natural Resources sources
[2]Does not include the value of limestone quarried for cement production
*Average number of persons during production period
**Processed or manufactured value
***Value not shown, but included in total
Note: Production represents shipments; numbers may not add to totals due to rounding

Table 1.3. Coal production for the calendar year 2002.

COMPANY	MINE NAME	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROX. VALUE($)[2]
			TONS	TONNES		
SURFACE MINING						
Brogan Mining Company Limited	Little Pond Mine	Alder Point, Cape Breton County	40,112	36 389	20	
Cape Crushing Company Limited	Merritt Point Mine	Alder Point, Cape Breton County	21,187	19 221	10	
Hill Reclamation Limited		Springhill, Cumberland County	10,396	9 432	6	
Pioneer Coal Limited	Stellarton Mine	Stellarton, Pictou County	246,801	223 897	23	
Thorburn Mining Limited	Coalburn Mine	Coalburn, Pictou County	93,458	84 785	9	
Total for all coal producers			411,954	373 724	68	20,000,000

[1]personnel employed in clerical, supervisory, etc. positions as well as mining personnel
[2]estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding

Figure 1.4 Location of coal mines in Nova Scotia, 2002.

trucks. Highwall ground control is enhanced using a large rock saw to establish pit walls.

The company conducted mining operations at the site from March through June, and September through December. Extensive reclamation work was conducted in January and February.

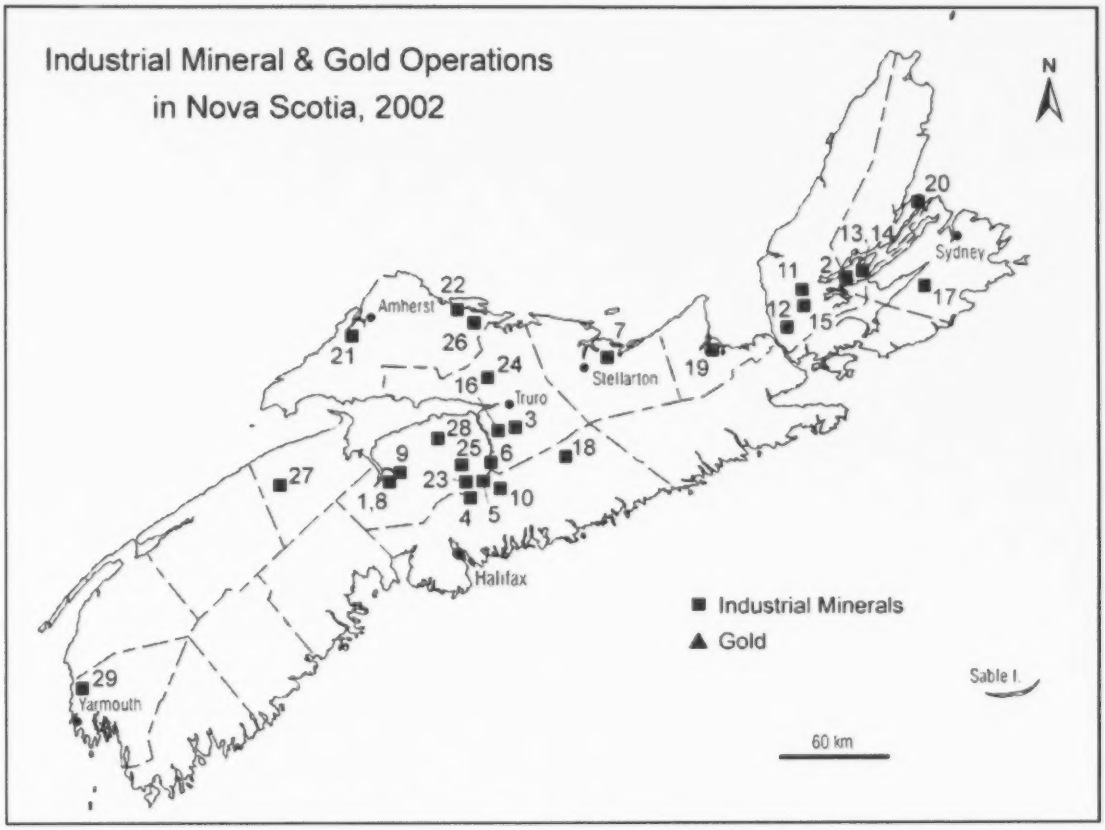
The coal mined at Stellarton is blended on-site with coal transported from the Coalburn Mine before being sold to Nova Scotia Power Inc. (NSPI) generating stations.

THORBURN MINING LIMITED

Manager: C. Chisholm
Address: PO. Box 1328
Antigonish, NS B2G 2L7
Production: 93,458 tons (84 785 tonnes) of coal
Employees: 9

The Coalburn surface mine is located in Coalburn, Pictou County. The mine began operations in June 1999, and extracts coal from both the Upper and Lower MacKay seams. The seams are approximately 1 metre in thickness. Mining is carried out using surface mining methods (including blasting) and highwall mining. Highwall mining is conducted using a remotely controlled coal-cutting machine that extracts coal in a series of headings driven from the exposed coal seam face at the toe of the highwall.

Production from the Coalburn Mine is blended at Pioneer Coal Limited's facility in Stellarton and supplied to NSPI.



Anhydrite
1. Fundy Gypsum Co.
2. Little Narrows Gypsum Co.

Barite
3. E-Z-EM Canada Inc.

Clay and Shale
4-7. Shaw Brick, a member of the Shaw Group Limited

Gypsum
8-9. Fundy Gypsum Co.
10. National Gypsum (Canada) Ltd.
11-12. Georgia-Pacific Corp.
13-14. Little Narrows Gypsum Co.

Marble
15. MacLeod Resources Limited

Limestone & Dolomite
16. Lafarge Canada Inc.
17. Nova Scotia Power Incorporated
18. Mosher Limestone Co. Ltd.
19. Ridge Brokers Ltd.
20. Scotia Limestone Ltd.

Salt
21. Sifto Canada Inc.
22. The Canadian Salt Company Limited

Silica Sand
23. Shaw Resources, a member of the Shaw Group Limited
24. Lafarge Canada Inc.

Dimension Stone
25. Scotia Slate Products Ltd.
26. Wallace Quarries Ltd.

Peat Moss
27. Annapolis Valley Peat Moss Co.
28. MacDonald Peat Moss Limited
29. Clare Organics Products Limited

Figure 1.5. Location of industrial mineral and gold operations in Nova Scotia, 2002.

Table 1.4. Industrial mineral production for the calendar year 2002.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROXIMATE VALUE ($)[2]
		TONS	TONNES		
GYPSUM					
Fundy Gypsum Company	Miller Creek and Wentworth Road, Hants County	1,624,470	1 473 710	185	
Georgia-Pacific Canada, Inc.	Melford and Sugar Camp, Inverness County	1,612,229	1 462 605	111	
Little Narrows Gypsum Company	Little Narrows, Victoria County	1,307,285	1 185 961	97	
National Gypsum (Canada) Limited	East Milford, Halifax County	3,123,300	2 833 439	97	
Total (gypsum)		7,667,284	6 955 715	490	80,037,000
ANHYDRITE					
Fundy Gypsum Company	Wentworth Road, Hants County	53,744	48 757	included in gypsum	
Little Narrows Gypsum Company	Little Narrows, Victoria County	49,032	44 482	included in gypsum	
Total (anhydrite)		102,776	93 239		1,073,000
SALT					
The Canadian Salt Company Limited	Pugwash, Cumberland County	953,162	864 703	196	
Sifto Canada Inc.	Nappan, Cumberland County	96,708	87 733	37	
Total (salt)		1,049,870	952 436	233	43,021,000
LIMESTONE AND DOLOMITE					
Lafarge Canada Inc.	Brookfield, Colchester County	585,187	530 878	16	
Mosher Limestone Company Limited	Upper Musquodoboit, Halifax County	25,353	23 000	23	
Nova Scotia Power Incorporated	Glen Morrison, Cape Breton County	113,267	102 755	10	
Ridge Brokers Limited	Southside Harbour, Antigonish County	4,540	4 119	1	
Scotia Limestone Limited	Kelly Cove, Victoria County			2	
Total (limestone and dolomite)		728,347	660,752	52	3,894,000[4]
BARITE					
E-Z-EM Canada Inc.	Brookfield, Colchester County	460	417	12	
Total (barite)		460	417	12	*

Table 1.4. Continued.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROXIMATE VALUE[2] ($)
		TONS	TONNES		
CLAY AND SHALE					
Shaw Brick (a member of the Shaw Group Limited)	Lantz and Milford, Hants County New Glasgow, Pictou County	34,171	31 000	see clay products Table 1.5	n/a[5]
Total (clay and shale)		34,171	31 000	see clay products Table 1.5	n/a[5]
SILICA SAND					
Shaw Resources (a member of the Shaw Group Limited)	Nine Mile River, Hants County	74,207	67 320	7	
Total (silica sand)		74,207	67 320	7	*
DIMENSION STONE					
Scotia Slate Products Ltd.	Rawdon Hills, Hants County	n/a	n/a	17	
Wallace Quarries Ltd.	Quarry: Wallace, (Sandstone) Cumberland County	9,524	8,640	6	
Total (dimension stone)		n/a	n/a	23	*
PEAT MOSS					
Annapolis Valley Peat Moss Company[2]	Berwick, Kings County	3,091	2 804	23	
Clare Organic Products Limited	Clare, Yarmouth County	1,180	1 071	n/a	
McDonald Peat Moss Limited[2]	Kennetcook, Hants County	1,294	1,174	30	
Total (peat moss)		5,566	5 049	n/a	713,000
AGGREGATES					
Crushed Stone	Various	9,266,547	8 406 556	243	56,740,000
Sand and Gravel	Various	5,230,625	4 745 192	127	20,609,000
Total (aggregates)		14,497,172	13 151 748	370	71,349,000
TOTAL FOR INDUSTRIAL MINERALS[6]		24,169,377[2]	21,926,316[2]	1 250[2]	210,358,000

*value not shown, but included in total
[1]total employees: mining, production, clerical, supervisory, etc.
[2]estimate from Nova Scotia Department of Natural Resources sources
[3]processed or manufactured value
[4]does not include the value of Lafarge Canada Inc. production, which value is included in the higher manufactured value (cement)
[5]value included in the higher manufactured valuation (bricks)
[6]excluding secondary mineral manufacturing (Table 1.5)
Note: production represents shipments, numbers may not add to totals due to rounding

Table 1.5. Secondary mineral manufacturing for the calendar year 2002.

COMPANY	LOCATION	PRODUCTION TONS	PRODUCTION TONNES	TOTAL NUMBER EMPLOYED[1]	APPROX. $VALUE[2]
CLAY PRODUCTS					
Shaw Brick (a member of the Shaw Group Limited)	Lantz, Hants County	34,171	31 000	48	*
PORTLAND CEMENT					
Lafarge Canada Inc.	Brookfield, Colchester County	334,394	303 360	65	*
TOTAL FOR SECONDARY MINERAL MANUFACTURING				113	38,574,000

*value not shown, but included in total
[1]total number of employees including office, clerical, supervisory, mining and production
[2]estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding

CAPE CRUSHING COMPANY LIMITED

Manager: E. Brogan
Address: PO. Box 265
North Sydney, NS B2A 3M3
Production: 21,187 tons (19 221 tonnes) of coal
Employees: 10

The company operates a small scale surface coal mine at Alder Point, Cape Breton County. The mine extracts coal from the Lloyd Cove (Bonar) seam using excavators, bulldozers and dump trucks. Following the recovery of remnants of underground coal pillars, the site is progressively backfilled and reclaimed to a more stable condition.

Product is sold to the local domestic home heating market and NSPI.

BROGAN MINING COMPANY LIMITED

Manager: R. Brogan
Address: 638 Bras d'Or Road
Florence, NS B1Y 1E4
Production: 40,112 tons (36 389 tonnes) of coal
Employees: 20

Brogan Mining Company Limited operated a small surface coal mine at Little Pond, Cape Breton County. Coal is mined from the Lloyd Cove (Bonar) seam in an area containing extensive underground mine workings. In 2002, mining progressed to the south and encountered the workings of the Alexander Mine.

The overlying overburden, waste rock and coal are mined and reclaimed using a dragline, bulldozers, excavators and dump trucks. The coal production is marketed to NSPI.

HILL RECLAMATION LTD.

Manager: M. McCormick
Address: R. R. #1
Springhill, NS B0M 1X0
Production: 10,396 tons (9 432 tonnes) of coal
Employees: 6

Hill Reclamation operates a coal recovery plant near Springhill, Cumberland County. The company reclaims coal from material excavated from an abandoned railway bed. Coal is recovered in a heavy media wash plant. The coal is marketed to NSPI.

Industrial Minerals Mining

Gypsum and Anhydrite

FUNDY GYPSUM COMPANY

Manager: K. Hillman
Address: PO Box 400
Windsor, NS B0N 2T0
Production: 53,744 tons (48 757 tonnes) of anhydrite
1,624,470 tons (1 473 710 tonnes) of gypsum
Employees: 185

The Fundy Gypsum Company operates quarries and crushing plants in the Wentworth Road and Miller Creek areas near Windsor, Hants County. In 2002, the company produced gypsum from its Miller Creek quarry and both gypsum and anhydrite from the Wentworth quarry. Rock is drilled, blasted and loaded onto trucks with loaders and hydraulic excavators.

The Wentworth ore is processed in the company's heavy media plant to separate anhydrite and gypsum.

Crushed gypsum and anhydrite are transported by unit train to ship-loading facilities at Hantsport, a distance of 19 km. These products are shipped to wallboard and cement plants in the United States and Canada.

GEORGIA-PACIFIC CANADA, INC.

Manager: J. T. Kennedy
Address: PO Box 400
Port Hawkesbury, NS B0E 2V0
Production: 1,612,229 tons (1 462 605 tonnes) of gypsum
Employees: 111

Georgia-Pacific Canada Inc. operates gypsum quarries at Sugar Camp and Melford, Inverness County. Gypsum is drilled, blasted and loaded onto trucks with loaders and hydraulic excavators at both mines.

Gypsum is transported by highway trucks to ship-loading facilities at Point Tupper, Richmond County. These products are shipped to wallboard and cement plants in the United States.

LITTLE NARROWS GYPSUM COMPANY

Manager: M. W. Bishop
Address: R. R. #1
Little Narrows, NS B0E 1T0
Production: 49,032 tons (44 482 tonnes) of anhydrite
1,307,285 tons (1 185 961 tonnes) of gypsum
Employees: 97

Little Narrows Gypsum Company operates a gypsum quarry and an anhydrite quarry near Little Narrows, Victoria County. The gypsum is drilled, blasted and loaded onto trucks with loaders and hydraulic excavators. All the gypsum and anhydrite produced is shipped from the company's dock on the Bras d'Or Lakes to destinations in Canada and the United States.

NATIONAL GYPSUM (CANADA) LTD.

Manager: P. C. Mills
Address: PO Box 57
Milford Station, NS B0N 1Y0
Production: 3,123,300 tons (2 833 439 tonnes) of gypsum
Employees: 97

National Gypsum (Canada) Ltd. operates the largest gypsum quarry in the province at East Milford, Halifax County. The gypsum is drilled, blasted and loaded onto trucks with loaders and hydraulic excavators. The gypsum is crushed, screened, and transported by unit train from Milford to Wright's Cove, Dartmouth, a distance of 45 km. Product is loaded onto ships for customers in Canada and the United States. The quarry also sells products within Nova Scotia for use in cement manufacturing.

Salt

THE CANADIAN SALT COMPANY LIMITED

Manager: A. W. Davidson
Address PO Box 160
Pugwash, NS B0K 1L0
Production: 953,162 tons (864 703 tonnes) of salt products
Employees: 196

The Canadian Salt Company Limited operates an underground salt mine at Pugwash, Cumberland County. The salt is mined by a room and pillar system of extraction, using diesel/electric drills, undercutters, loaders and trucks. Production during the year was from the 1000 and 830 levels.

The processing plant at the site produces a wide range of salt products, including industrial grades of salt, salt blocks for farm use, and refined salt for domestic consumption. Transportation is by road, rail or from the company owned ship-loading facility at Pugwash.

SIFTO CANADA INCORPORATED

Manager: D. E. Dickie
Address: PO Box 550
Amherst, NS B4H 4A1
Production: 96,708 tons (87 733 tonnes) of salt products
Employees: 37

Salt has been produced from the solution salt mine at Nappan, Cumberland County, since 1947. Salt is extracted by solution mining where water is pumped in underground wells and the salt is dissolved. The resulting brine solution is then returned to the surface. The salt is recovered from the brine in a processing plant, using a 'mechanical vapour recompression evaporating process' system. The plant produces a wide range of refined salt products.

Development continued on two new brine wells that were drilled in 2001. Salt was produced from the Nos. 7, 9, and 10 brine wells.

Barite

E-Z-EM CANADA, INC., NYSTONE DIVISION

Manager: V. J. Prostak
Address: PO Box 69
Debert, NS B0M 1G0
Production: 460 tons (417 tonnes) of pharmaceutical barite
Employees: 12

E-Z-EM Canada's barite deposit is located 1.6 km northeast of Brookfield, Colchester County. During 2002, there was no production from the surface mine; however, 2369 tonnes of ore previously trucked to the company's plant at Debert were processed to a pharmaceutical grade product. The refined product is shipped to the parent company, E-Z-EM Corporation, New York, USA, for further processing and packaging.

Limestone and Dolomite

LAFARGE CANADA INC.

Manager: J. Cross
Address: PO Box 5
Brookfield, NS B0N 1C0
Production: 585,187 tons (530 878 tonnes) of limestone
Employees: 16 (quarry) 65 (cement plant)

Lafarge Canada Inc. operates a limestone quarry and crushing plant adjacent to its Brookfield cement plant. The plant is located in Pleasant Valley, 5 km west of Brookfield, Colchester County. Overburden is removed and limestone and waste rock are drilled, blasted and loaded on off-road haul trucks by excavators.

During 2002 cement kiln #2 operated for eleven months and kiln #1 operated for three months. All of the limestone produced from the quarry is used to manufacture Portland cement products.

MOSHER LIMESTONE COMPANY LIMITED

Manager: D. M. Mosher
Address: PO Box 28
Upper Musquodoboit, NS B0N 2M0
Production: 25,353 tons (23 000 tonnes) of dolomite/limestone
Employees: 23

Mosher Limestone operates a number of quarries near Upper Musquodoboit, Halifax County. In 2002 production was limited to the Hutchinson Settlement quarry. The company produces agricultural grade dolomite/limestone in its grinding plant at Upper Musquodoboit. The product is bagged or supplied in bulk for distribution throughout the Atlantic Provinces. The company also produces a pelletized limestone product for the domestic garden market.

NOVA SCOTIA POWER INCORPORATED (OPERATED BY KELLY ROCK LIMITED)

Manager: D. W. MacKenna (Kelly Rock Limited)
Address: PO Box 1206
Sydney, NS B1P 6J9

Production: 113,267 tons (102 755 tonnes) of limestone
Employees: 10

The limestone quarry at Glen Morrison, Cape Breton County, began production in 1993. The company produces several products at the on-site milling facility. During 2002, most of the production from this site was shipped to Point Aconi for use in the NSPI fluidized bed power generating station. Kelly Rock Limited operates the quarry on behalf of Nova Scotia Power.

RIDGE BROKERS LIMITED

Manager: E. Alward
Address: PO Box 2001
Havelock, NB E4Z 6H3
Production: 4,540 tons (4 119 tonnes) of limestone
Employees: 1

The company operates a small quarry at Southside Antigonish Harbour, Antigonish County, producing limestone for the agricultural market.

During 2002, no mining or crushing took place. Limestone was shipped from on-site crushed rock stockpiles.

SCOTIA LIMESTONE LIMITED

Manager: D. M. Mosher
Address: PO Box 28
Upper Musquodoboit, NS B0N 2M0
Employees: 2

The Kelly's Cove dolomite quarry and plant operation is located near New Campbellton, Victoria County. The plant produces an agricultural grade dolomite for domestic sale, a ground dolomite product for coal mine stone dust, and dolomite products for the offshore steel industry. In 2002 there was limited recrushing and grinding from on-site ore inventory. No mining took place at the site during the year.

Marble

MACLEOD RESOURCES LIMITED

Manager: C. Trider
Address: PO Box 10
River Denys, NS B0E 2Y0
Production: 0 tons (0 tonnes) of marble
Employees: n/a

MacLeod Resources was issued a mining permit in November 2002 to mine marble at River Denys. Site activity included the construction of buildings associated with future mining activities.

Clay

SHAW BRICK, A MEMBER OF THE SHAW GROUP LIMITED

Manager: B. Frizzell
Address: PO Box 2130
Lantz, NS B0N 1R0
Production: 34,171 tons (31 000 tonnes) of clay & shale
Employees: 48

Shaw Brick extracts clay from pits at Lantz, Milford and Shubenacadie, all in Hants County, and shale from quarries located in Hardwoodlands, Hants County, and New Glasgow, Pictou County. These materials are used in the company's plant in Lantz for the manufacture of bricks and other structural clay products.

Silica Sand

SHAW RESOURCES, A MEMBER OF THE SHAW GROUP LIMITED

Manager: S. Smith
Address: PO Box 60
Shubenacadie, NS B0N 2H0
Production: 74,207 tons (67 320 tonnes) of silica sand
Employees: 7

Shaw Resources produces silica sand from a deposit at West Indian Road, Hants County. This sand is processed into several silica sand products including glass-grade sand.

In 2002 all production came from existing on-site stockpiles.

Dimension Stone

WALLACE QUARRIES LIMITED

Manager: S. Flynn
Address: PO Box 203
Wallace, NS B0K 1Y0
Production: 9,524 tons (8 640 tonnes) of building stone
Employees: 6

The Wallace Quarries, located near Wallace, Cumberland County, continued to supply building stone for major building rehabilitation work in Halifax and central Canada. Blocks of stone are sent for cutting to processing facilities in Nova Scotia, New Brunswick and Quebec to supply local markets.

Slate

SCOTIA SLATE PRODUCTS LTD.

President: D. Donovan
Address: Box 12, Comp 3
Kennetcook, NS B0N 1P0
Employees: 17

The company produces a range of slate products from its quarry at Rawdon Hills, Hants County.

Peat Moss

ANNAPOLIS VALLEY PEAT MOSS COMPANY LIMITED

President: H. Endres
Address: Berwick, NS B0P 1E0
Production: 3,091 tons (2 804 tonnes) of peat moss
Employees: 23

The company uses vacuum harvesters to recover agricultural peat from a 200 ha bog located near Berwick, Kings County. Baled peat products are shipped to markets in Canada, the United States and Japan.

CLARE ORGANIC PRODUCTS LIMITED

President: G. Thimot
Address: 30 Common Cross Rd. RR#1
Box 174A
Saulnierville NS B0W 2Z0
Production: 1,180 tons (1 071 tonnes) of peat moss
Employees: n/a

MACDONALD PEAT MOSS LIMITED/ TOURBIERE MACDONALD LIMITEE

Owner: Lameque Quality Group Ltd.
Address 86 Tourbe Street
Lameque, NB E8T 1A3
Production: 1,294 tons (1 174 tonnes) of peat moss
Employees: 30

MacDonald Peat Moss Limited, a wholly-owned subsidiary of New Brunswick's Lameque Quality Group Ltd., has lease rights to a 688 ha peat bog located on Crown land, approximately 12 km west of Kennetcook, Hants County. The company began operations in 1999, exporting baled peat to international markets.

Aggregate Resources

Approximately 13.2 million tonnes of construction aggregate were produced in Nova Scotia in 2002. Crushed stone production totalled 8.4 million tonnes and sand and gravel production totalled 4.75 million tonnes. The majority of the aggregate was sold within the province with some transported by barge for the export market.

Appendix 2

Mineral Resources Branch Geoscience Maps and Publications for Sale*

Maps

Bedrock Geology Maps

Provincial Scale

1:2 000 000

Map ME 1979-6 Metamorphic Map of Nova Scotia, by J. D. Keppie and G. K. Muecke, 1979, scale 1:2 000 000. **FREE** (Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)

Map ME 1979-4 Geological Map of Nova Scotia, by J. D. Keppie, 1979, scale 1:2 000 000. **FREE** (Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)

1:500 000

Map ME 2000-1 Geological Map of the Province of Nova Scotia, by J. D. Keppie, 2000, scale 1:500 000. **$20.00**

Regional Scale

1:250 000

Map ME 1994-1 Geological Map of the South Mountain Batholith, Western Nova Scotia, by M. A. MacDonald with contributions from M. C. Corey, L. J. Ham and R. J. Horne, 1994, scale 1:250 000. **$6.00**

1:125 000

Map ME 1978-1 Preliminary Geology Map of the Cobequid Highlands, by H. V. Donohoe and P. I. Wallace, 1978, scale 1:125 000, (superseded by Map ME 1982-6, Map ME 1982-7, Map ME 1982-8, Map ME 1982-9, scale 1:50 000). **$3.50**

1:100 000

Map ME 2001-1 Map of Bedrock Aggregate Potential in the Halifax-Dartmouth Metropolitan Area Nova Scotia, by G. Prime, 2001, scale 1:100 000. [accompanies Economic Geology Series ME 2001-1.] **$5.00**

Map ME 1998-1 Preliminary Geological Map of Guysborough, Richmond and Antigonish Counties (parts of NTS sheets 11E/08, 11F/05, 11F/06, 11F/10, 11F/11, 11F/12 and 11F/15, Nova Scotia, Canada, by C. E. White and S. M. Barr, 1998, scale 1:100 000. **$5.00**

Map ME 1984-2 Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia, by S. M. Barr and J. R. D. Setter, 1984, scale 1:100 000. **$4.00**

Detailed Scale

1:50 000

Map ME 2001-1 Geological Map of the Meguma Group in the Rawdon Area [part of 11E/04], Hants County, Nova Scotia, by R. J. Horne, L. A. MacDonald, M. S. King, 2001, scale 1:50 000. **$5.00**

Map ME 2003-3 Preliminary Geological Map of the Wolfville/Windsor Area, Hants and Kings Counties, Nova Scotia [21H/01 and Parts of 21A/16C and D], by R. G. Moore, S. A. Ferguson, R. C. Boehner, C. M. Kennedy, 2000, scale 1:50 000. **$5.00**

*For a list of free digital products available for download, please access the branch web site: http://www.gov.ns.ca/natr/meb

Appendix 2, 2004. *in* Mineral Resources Branch, Report of Activities 2003; Nova Scotia Department of Natural Resources, Report 2004-1, p. 153-199

Map ME 1999-3 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/15], Nova Scotia, by L. J. Ham, 1999, scale 1:50 000. **$5.00**

Map ME 1999-2 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/14], Nova Scotia, by L. J. Ham, 1999, scale 1:50 000. **$5.00**

Map ME 1996-1 Geological Map of the Shubenacadie and Musquodoboit Basins Showing the Extent of Early Cretaceous Sediments (part of NTS Map Sheet 11E/03), Colchester and Halifax Counties, Nova Scotia, by R. R. Stea, P. W. Finck, S. E. Pullan, and M. C. Corey, 1996, scale 1:50 000. **$6.00**

Map ME 1994-8 Geological Map of Bridgetown, Nova Scotia (NTS Sheet 21A/14), by M. A. MacDonald and L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-7 Geological Map of Digby, Nova Scotia (NTS Sheet 21A/12), by L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-6 Geological Map of Milford, Nova Scotia (NTS Sheet 21A/11), by M. C. Corey and R. J. Horne, 1994, scale 1:50 000. **$6.00**

Map ME 1994-5 Geological Map of Kejimkujik Lake, Nova Scotia (NTS Sheet 21A/06 and part of 21A/07), by R. J. Horne and M. C. Corey, 1994, scale 1:50 000. **$6.00**

Map ME 1994-4 Geological Map of Weymouth, Nova Scotia (NTS Sheet 21A/05), by M. A. MacDonald and L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-3 Geological Map of Wentworth Lake (NTS Sheet 21A/04 and part of 20P/13), by L. J. Ham and M. A. MacDonald, 1994, scale 1:50 000. **$6.00**

Map ME 1994-2 Geological Map of Lake Rossignol, Nova Scotia (NTS Sheet 21A/03 West Half), by M. C. Corey and R. J. Horne, 1994, scale 1:50 000. **$6.00**

Map ME 1993-1 Geological Map of New Germany (NTS Sheet 21A/10), Nova Scotia, by R. J. Horne, 1992, scale 1:50 000. **$6.00**

Map ME 1992-1 Geological Map of Gaspereau Lake (NTS Sheet 21A/15 and part of 21H/02), Nova Scotia, by M. A. MacDonald and L. J. Ham, 1992, scale 1:50 000. **$6.00**

Map ME 1990-14 Cumberland Basin Geology Map, Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties, by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000. **$6.00**

Map ME 1990-13 Cumberland Basin Geology Map, Oxford and Pugwash, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. **$6.00**

Map ME 1990-12 Cumberland Basin Geology Map, Amherst, Springhill and Parrsboro, Cumberland County, by R. J. Ryan, R. C. Boehner, A. Deal and J. H. Calder, 1990, scale 1:50 000. **$6.00**

Map ME 1990-11 Cumberland Basin Geology Map, Apple River and Cape Chignecto, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. **$6.00**

Map ME 1990-10 Geological Map of Windsor (21A/16, West Half and part of 21H/01), Nova Scotia, by L. J. Ham, 1990, scale 1:50 000. **$6.00**

Map ME 1990-9 Geological Map of Chester (21A/09), Nova Scotia, by M. C. Corey, 1990, scale 1:50 000. **$7.00**

Map ME 1989-4 Geology of Mabou Highlands (NTS sheet 11K/03, west half), Nova Scotia, by S. M. Barr and A. S. Macdonald, 1989, scale 1:50 000 (accompanies Paper ME 1989-2). **$3.00**

Map ME 1987-8 Bedrock Geological Map of Mount Uniacke (11D/13 West), by M. C. Corey, 1987, scale 1:50 000. **$6.00**

Map ME 1987-7 Bedrock Geological Map of Windsor (21A/16 East), by L. J. Ham and R. J. Horne, 1987, scale 1:50 000. **$6.00**

Map ME 1987-6 Bedrock Geological Map of Halifax and Sambro (11D/12 and 11D/05), by M. A. MacDonald and R. J. Horne, 1987, scale 1:50 000. **$6.00**

Map ME 1986-1 Geological Map of the Sydney Basin, Cape Breton Island, Nova Scotia, by R. C. Boehner and P. S. Giles, 1986, scale 1:50 000. **$5.00**

Map ME 1985-2 Geological Map of the Loch Lomond Basin and Glengarry Half Graben, by R. C. Boehner and G. Prime, 1985, scale 1:50 000. **$5.00**

Map ME 1982-9 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Debert - Mt. Thom Region, Sheet 4 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, 1982, scale 1:50 000. **$8.00. $25.00 for set of Map ME 1982-6 to Map ME 1982-9**.

Map ME 1982-8 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Economy River - Folly Lake Region, Sheet 3 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, 1982, scale 1:50 000. **$8.00. $25.00 for set of Map ME 1982-6 to Map ME 1982-9.**

Map ME 1982-7 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Parrsboro - Five Islands Region, Sheet 2 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, 1982, scale 1:50 000. **$8.00. $25.00 for set of Map ME 1982-6 to Map ME 1982-9.**

Map ME 1982-6 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Advocate Harbour - Port Granville Region, Sheet 1 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, 1982, scale 1:50 000. **$8.00. $25.00 for set of Map ME 1982-6 to Map ME 1982-9.**

Map ME 1982-5 Geological Map of the Northern Antigonish Highlands, Nova Scotia, by J. B. Murphy, J. D. Keppie and A. Hynes, 1982, scale 1:50 000. **$4.00**

Map ME 1982-4 Geological Map of the Shubenacadie and Musquodoboit Basins, by P. S. Giles and R. C. Boehner, 1982, scale 1:50 000. **$5.00**

Map ME 1982-3 Geological Map of the Eureka Area, by P. S. Giles, 1982, scale 1:50 000. **$3.00**

Map ME 1982-2 Geological Map of the Antigonish Basin, by R. C. Boehner and P. S. Giles, 1982, scale 1:50 000. **$3.00**

1:31 680

Map ME 1967-3 Geology, Area of Christopher McLeod Brook, Victoria County, Nova Scotia, by G. C. Milligan, B. White, R. M. Creed and A. K. Chatterjee, 1967, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1967-2 Geology, Middle River Area, Inverness and Victoria Counties, Nova Scotia, by G. C. Milligan, B. White, R. M. Creed and A. K. Chatterjee, 1967, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1967-1 Geology, Crowdis Mountain Area, Victoria County, Nova Scotia, by G. C. Milligan, R. C. Parsons, B. White, R. M. Creed and A. K. Chatterjee, 1967, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1963-2 Geology, Boisdale Hills, Scotch Lake to Steeles Crossing, Cape Breton County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1963, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1963-1 Geological Map of the Creignish Hills, Inverness County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1963, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1962-1 Geology, North Mountain, Inverness County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1962, scale 1:31 680 (accompanies Memoir ME 7). **$1.00**

1:25 000

Map ME 1997-1 Geological Map of a Portion of the South-Central Cape Breton Highlands (part of NTS map sheet 11K/07), Victoria and Inverness Counties, Nova Scotia, by L. J. Ham, 1997, scale 1:25 000. (accompanies Paper ME 1997-1). **$6.00**

Map ME 1995-2, Second Edition Geological Map of a Portion of the South-Central Cape Breton Highlands (parts of NTS Map Sheets 11K/07 and 11K/10), Victoria and Inverness Counties, Nova Scotia, by R. J. Horne, revised September 1996, scale 1:25 000. **$6.00**

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Map ME 1979-013 Pleistocene geology map of the Eastern Shore Region, Guysborough and Halifax Counties, Nova Scotia [sheet 2 of 3] [11E/01 and parts of 11E/02, 11E/07, 11E/08, 11E/11, 11F/04, 11F/05, 11C/13, 11D/15 and 11D/16, by R. R. Stea and J. H. Fowler, 1979, scale 1:100 000. **$4.00**

Map ME 1979-012 Pleistocene geology map of the Eastern Shore Region, Guysborough County, Nova Scotia [sheet 1 of 3] [11F/06 and parts of 11F/03, 11F/04, 11F/05, 11F/07, 11F/11 and 11F/12], by R. R. Stea and J. H. Fowler, 1979, scale 1:100 000. **$4.00**

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OFM ME 2001-1 Map of Bedrock Aggregate Potential in the Halifax-Dartmouth Metropolitan Area Nova Scotia, by G. Prime, 2001, scale 1:100 000. [accompanies Economic Geology Series ME 2001-1.] **$5.00**

OFM ME 1986-49 to OFM 1986-56 Gold Compilation of the Meguma Terrane in Nova Scotia (8 maps), by J. McMullin, G. Richardson, T. Goodwin, 1986, scale 1:100 000. **$2.00 each**

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Publications

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Mineral Resources Act and Regulations, S.N.S. 1990, c. 18. **$9.35**

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Bulletins

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Bulletin ME 5 Salt and Potash Resources in Nova Scotia, by R. C. Boehner, 1986, 346 pages, 8½" x 11" format, includes Map ME 1983-3, scale 1:500 000. **$17.00 (Microfiche $5.00)**

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Continental Rifting, by L. A. MacDonald, S. M. Barr, C. E. White, J. W. F. Ketchum, 2002; *in* Canadian Journal of Earth Sciences, vol. 39, pages 259-277. **FREE**

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OP ME 2003-1 Fundy Mineral Collecting, by I. Booth, 2003, 127 pages. (This guidebook describes fifty notable localities for collecting the Fundy zeolites and semi-precious minerals). **$20.00**

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